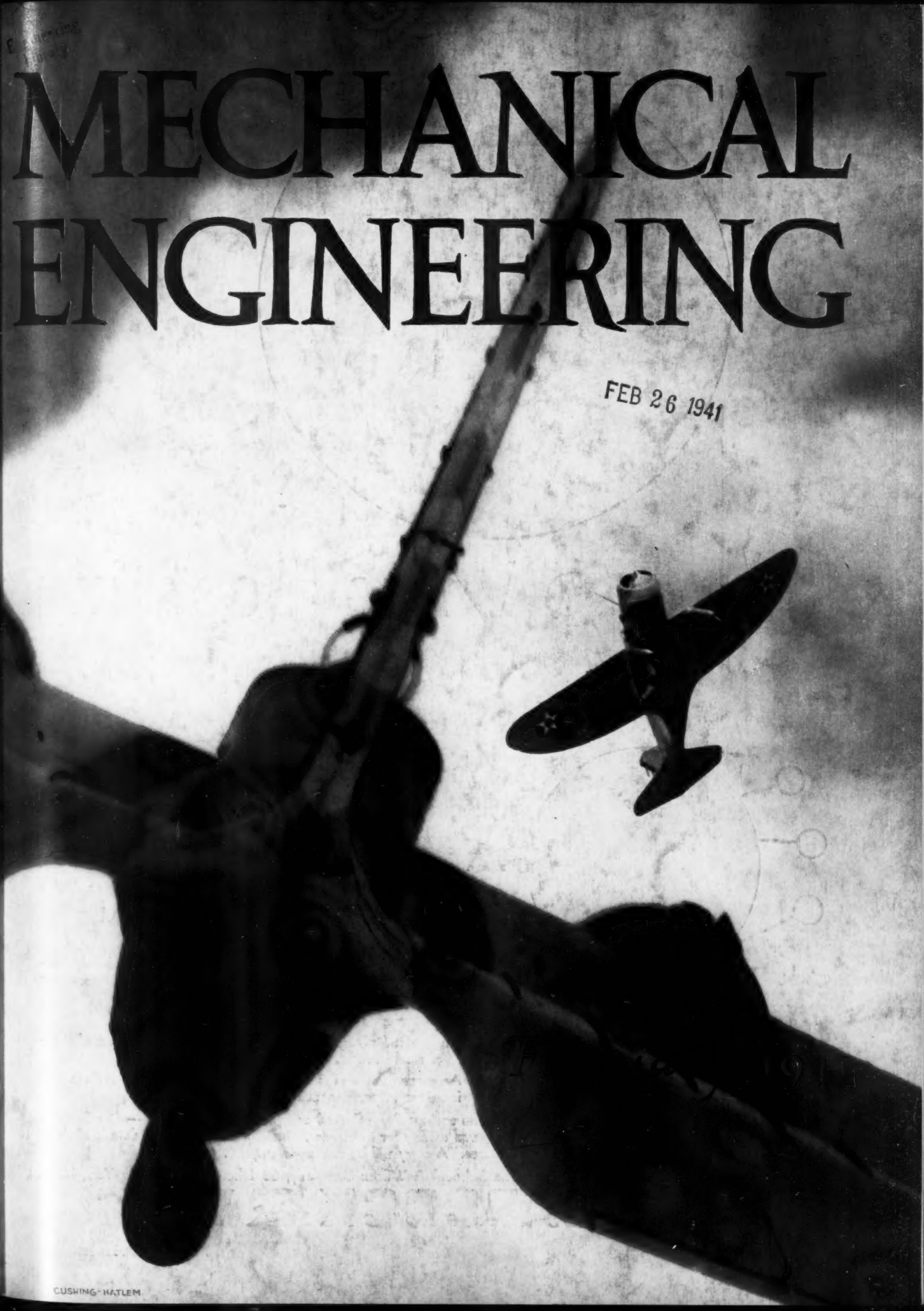
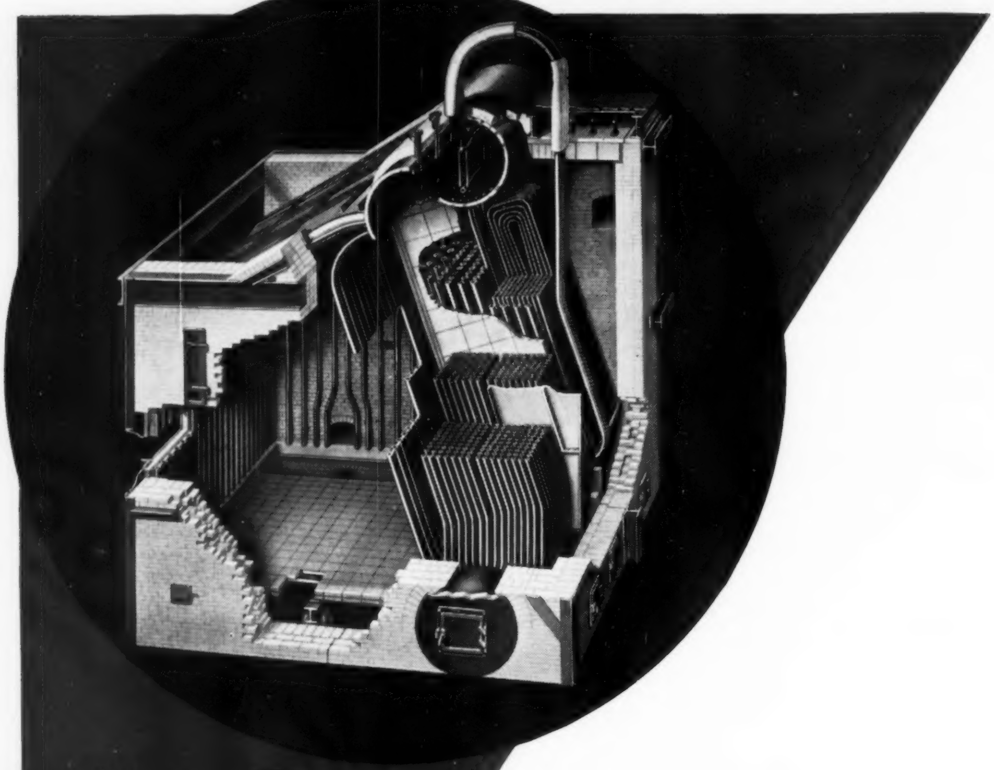
MECHANICAL ENGINEERING





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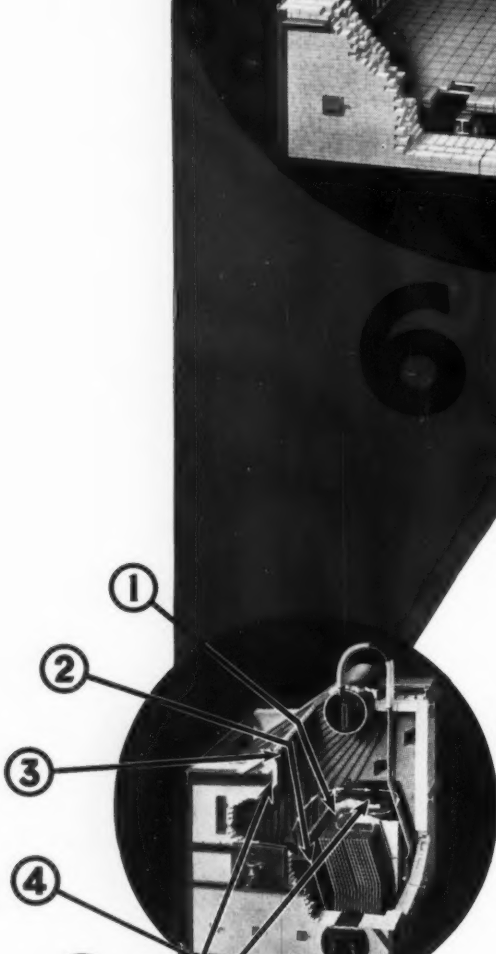

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1. The division wall between the furnace and boiler does double duty, with both sides utilized as heating surface . . . cutting down wall cost.
2. Normally only two wall headers are required.
3. The Stud-Tube sidewalls and roof—of incomparable durability—are fabricated most economically by special equipment that slices manufacturing costs to the bone.
4. No basement is necessary—saving installation costs.
5. The method of support minimizes the amount and cost of structural steel needed.
6. An arrangement of superheater and boiler heating surface that is unique in performance and low cost.

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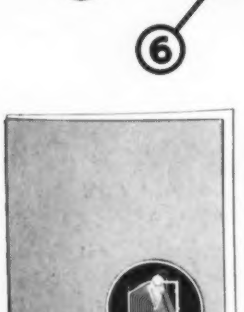

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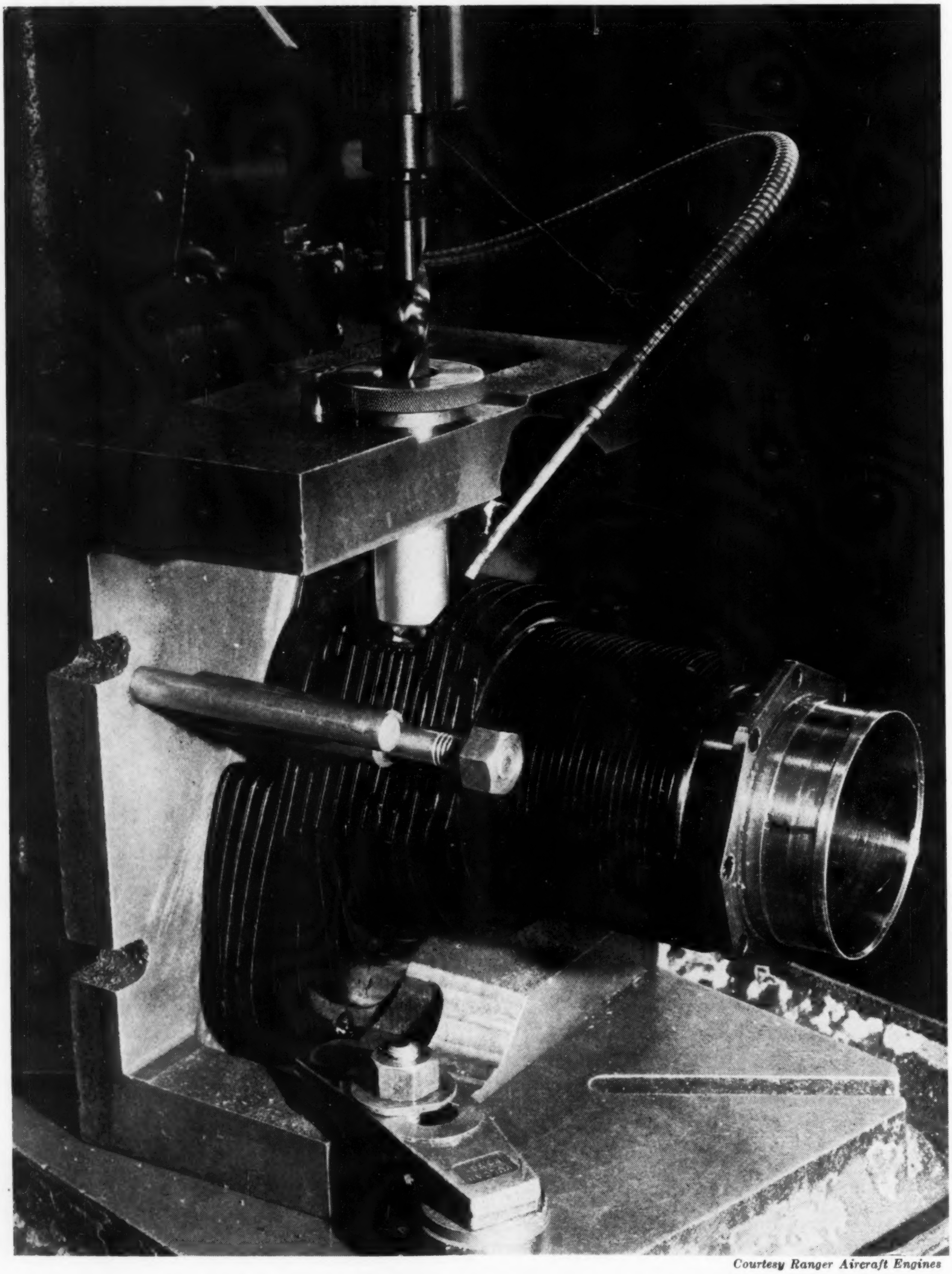


Courtesy Ranger Aircraft Engines

Machines on the Job—Removing a Spark Plug Insert From an Aircraft-Engine Cylinder

Volume 63
No. 2

MECHANICAL ENGINEERING

February
1941

GEORGE A. STETSON, *Editor*

Engineers Against Time

As THE program of national defense swings further into the "all-out" stage, demands on engineers and engineering societies increase rapidly to the point where it becomes the exception, rather than the rule, to find men concerned primarily with peacetime pursuits. So rapidly has the first stage of the change taken place that ideal production conditions cannot be expected to exist, and the necessity is faced of adapting commercial plants, equipment, and man power to munitions manufacture in the broadest sense of that term, which may be used to cover whatever needs in production the nation must provide.

Time, as has been emphasized over and over again, is the essence of the program. The race has become one of "engineers against time," so that this phrase correctly expresses the challenge to their talents and energy that engineers have taken up. "Engineers against time" is the keynote of the contribution The American Society of Mechanical Engineers, under the leadership of its active Committee on National Defense, is striving to make.

The nation looks to engineers—and particularly to mechanical engineers—no less than to the Administration and to the Army and Navy to win this race against time. Familiar as they are with the amazing triumphs of mass production, the nation and its leaders have almost unlimited faith in the ability of engineers to accomplish any task, no matter how preposterous, set before them. No engineer doubts that the faith is well founded, but it is a sobering thought to realize that the time element is largely neglected by the layman. Warnings on this score have been uttered by men of national reputation, but warnings and explanations of the part time plays will not be accepted as alibis in case of disappointment or failure, no matter how reasonable they may be. The impossible is being demanded of engineers. It is up to engineers to accomplish the apparently impossible. Otherwise engineers will find themselves discredited, and the injustice of the popular verdict will be but cold comfort indeed.

The American Society of Mechanical Engineers began its race against time many years ago when, following the World War, it maintained a National Defense Division, recently reorganized as its National Defense Committee. Through members of the Division the Society played an important if inconspicuous part in laying plans and devising ways by which the delays and confusion of a shift from peacetime to wartime conditions in plants likely to be called upon to produce for the needs of the Army and Navy could be saved. That the nation finds itself in a better position than it was in at the start of the World War no one who has knowledge of the facts will deny. But those most intimately "in the know" have long realized how great the demands would be and have tried to prepare for them. They were getting ready for the engineers' race against time. As soon as the demand came for increased effort, the Society took the steps necessary to meet it.

The National Defense Committee was reorganized with a membership that includes prominent engineers and industrialists. Early last fall the Society began to make effective use of its function in organizing meetings for the discussion of technical problems. The thin ribbon of papers on national-defense topics that had run through its general meetings for two decades suddenly broadened into a wide band of specific information, as was demonstrated at the two highly successful "shell" meetings held in September and October and led up to the third, to be held at Cleveland March 12 and 13, as announced on page 162 of this issue. The race of engineers against time is now going on in deadly earnest.

In the announcement of the Cleveland meeting the Committee on National Defense has attempted to emphasize the importance of intensive effort in adapting existing commercial plants, equipment, and man power to accomplish the increased production demanded by world conditions. By means of the meeting the Committee hopes to drive home this idea, and to afford, through the interchange of experience and knowledge, specific information on how increased production can be secured and how the unfamiliar products required in the national-defense program can be provided in the shortest time. The Committee will provide the forum, the program, and the principal speakers, but the value of its effort will depend on the cooperation of the engineers who seize upon the opportunity to learn what they can from the experts and also from one another. It is their race against time.

Adapting Skill and Ideas

USEFUL as the A.S.M.E. national-defense meetings are to the nation, there are countless other ways in which the Society is doing its best to speed up the engineers' race against time. By the time this issue appears the A.S.M.E. national secretary, C. E. Davies, will be on active duty in the Ordnance Department in Washington, on a leave of absence granted by the Council on the grounds that by making the secretary's services available to the War Department the Society is benefiting the

nation. Mr. Davies has a wide acquaintanceship among mechanical engineers. He will be in close contact with A.S.M.E. headquarters where he can tap sources of positive information on the skills possessed by A.S.M.E. members recorded by themselves and attested by records of experience. In the race of engineers against time it will profit the nation immeasurably to be able to lay its finger on men who are competent to adapt their skills and ideas to the needs of national defense.

An excellent example of Society cooperation in engineers' efforts to adapt their skill and ideas to the solution of problems raised by the national-defense program is the nomination by President Hanley of Col. James L. Walsh, chairman of the A.S.M.E. Committee on National Defense, to the Committee on Protection of Civilians in Time of War, which has been appointed by Henry L. Stimson, Secretary of War, under the chairmanship of Walter D. Binger, Commissioner of Borough Works of Manhattan. In his letter to George T. Seabury, secretary A.S.C.E., announcing appointment of a representative of the A.S.M.E. to this committee, Mr. Hanley said: "Colonel Walsh will be able to call upon any other particular skills that are needed to round out the experience necessary to solve your problems."

The committee, which is made up of representatives of seven national engineering societies, will, Mr. Stimson said, be of value to the War Department "in matters which concern the protection of the civil population from air and other attack." It will be provided by the War Department, he further announced, "with pertinent information of the very latest successful methods employed abroad to safeguard civilian communities against air and other attack." Here again, as demonstrated by tragic events in Great Britain and on the Continent, engineers are entering a vital race against time, and are afforded an opportunity to adapt their skills and ideas to the protection of their fellow citizens.

Time by the Forelock

IN THE race of engineers against time there are other aspects equally as important as maximum production and the intelligent adaptation of plant, equipment, man power, skills, and ideas. Engineers must take time by the forelock. They must maintain, speed up, and give direction to researches upon which the superiority of this nation over others depends. In the short-range and specialized view of this need for research lies the hope that we shall be able to offer to the defenders of democratic institutions that extra speed of aircraft, that extra striking power of weapons, that extra precaution against attack, that extra provision for the daily needs of people that will weigh heavily in the scales of victory. In the long-range and more generalized view lies the hope that we may avoid at least the worst effects of readjustment and reconstruction likely to follow with the return of peace. Here are two other aspects of the race of engineers against time.

An excellent example of both the long-range and the short-range implications of research in engineering is to be found in the annual report of the National Advisory Committee for Aeronautics, of which Vannevar Bush is chairman, submitted to the President on January 13. Reasons of state prevented publication by the N.A.C.A. of the technical portions of its report that in previous years were made public. But it is in the published conclusion of the report that the example referred to will be found. It reads in part:

> Scientific research is the most fundamental activity of the Government in connection with the development of America's potential strength in the air. No matter how greatly production facilities may be increased, no matter how many pilots may be trained, unless the aircraft that are built for action are at least equal in performance to those of any possible enemy, the whole effort will be largely wasted.
>
> It is the responsibility of the National Advisory Committee for Aeronautics to anticipate the research needs of aviation, and the progress that can be made, and to provide the Army, the Navy, and the industry in the United States with a constant flow of the new knowledge that is essential to American leadership in aircraft performance.
>
> In the scientific study of the problems of flight, the talent of America has been marshalled through the technical subcommittees and through the stimulation and coordination of research in scientific and educational institutions. Progress in military and naval aviation will find reflection in improved performance, efficiency, and safety of civil and commercial aviation. The Committee believes that commercial aviation will prove of ever-increasing importance to the United States in promoting international trade and good will, especially in the Western Hemisphere. When the present wars have ended, aviation will have an opportunity to prove its real value to civilization in shortening the distances between nations and in facilitating international trade and commerce. When that day comes, the extension of world trade routes of the air will bring some compensation for the awful destruction wrought and to be wrought by military aviation before peace again prevails.

Generalize a few words in the foregoing statement and the fundamental philosophy upon which this nation must rely in order to secure and maintain the superiority necessary for successful future development is expressed. Only by taking time by the forelock, as it were, and making effective and intelligent use of our abilities in research can we hope to survive as a first-rate nation. The engineer's responsibility in this forward-looking action is particularly heavy. For upon engineers will rest a large portion of the burden of technical progress upon which the prosperity and happiness of nations in this era depend.

The need for planning for post-war adjustments was called to the attention of mechanical engineers by W. L. Batt in the A.S.M.E. Annual Dinner address published last month. Quick to grasp the significance of Mr. Batt's message, the Society has suggested to A.S.M.E. groups all over the country that the address be studied in the hope that engineers may exert local and national leadership in preparing for the difficult days that will follow the present war. These days are far away, but that they are being thought about is shown not only by Mr. Batt's address but also by Mr. Freeman's review on page 125 and the report of the A.A.A.S. meeting on inter-American relations, pages 136–140.

TECHNICAL PROGRESS *in* AVIATION

By J. C. HUNSAKER

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE increasing importance of the airplane in our normal social and economic life is just now overshadowed by its dominant part in our national security. When recent advances in the aeronautical sciences are being tested on a grand scale in the proving ground of war, we naturally lose interest in the possibilities of those same advances in applied science as they might assist our peacetime communications. If we hope to live in a kind of world in which individual living is worth while, our thought must be focused on the airplane as an instrument of air power—destructive or protective.

That important technical progress has been made in the development of the airplane is obvious from the reports of dive bombings, night bombings, and aerial torpedo attacks on the one hand, and from reports of effective defensive action by fast fighting planes on the other hand. Guns, armor, radio, fuels, meteorology, metallurgy, and photography are also contributing through technical advances to the effectiveness of the airplane in war. Attack and defense for colossal stakes stimulate development in every branch of applied science.

Technical progress in the development of the airplane as a vehicle of the air has been especially marked in the last ten years. Some steps in this progress have been abrupt, because they were the consequence of inventions. True inventions are unpredictable, but it is our experience that when new knowledge obtained by research and experiment becomes generally known, the invention necessary for its practical application soon follows. Whether the invention can then be applied by designers to realize a technical improvement in the airplane depends on whether the state of the art is ripe for it.

For example, the aerodynamic advantages of an unbraced monoplane wing were demonstrated by Fokker in the days of braced biplanes, but the safe construction of such wings had to wait for the availability of light aluminum alloys. Likewise the advantage of retracting the landing gear and wheels was recognized at an early date and mechanisms for retraction were invented, but no designer would bother with them until speeds were high enough to make it worth while to accept the added cost and complication. The designer of transport planes, moreover, needed a thick cantilever wing to afford space enough to house the wheels in the retracted position. Consequently, there was a lag of some ten years in the general adoption of this improvement.

Though some technical improvements are thus proposed before the art has sufficiently advanced to permit their use, other improvements come about as a result of difficulties created by advance in the art. One example of these is the mass balancing of control surfaces to prevent unstable vibration or "flutter" of cantilever wings. Serious flutter trouble was not encountered until experience was had with high-speed monoplanes and particularly with dive bombers. The cure for the trouble was discovered after the trouble was disclosed.

When airplanes fly very fast, moreover, roughness of the external surfaces is found to be extremely costly in power. As a result, we now have flush rivets, spot-welding techniques, and other means to help make a smooth wing.

In general, the results of methodical research and experiment lead to new knowledge and to technical progress. But technical progress, of itself, discloses new difficulties whose solution requires further research. From this solution, further technical gains may result.

Under the stimulus of war, this self-generation of technical advances is unnaturally accelerated, but the direction of the progress is likely to be toward immediate objectives. For fighting planes every effort will be made to improve the vital performance characteristics of speed and climb, regardless of expense in power and fuel. Bombers must take off with a maximum load of bombs without regard to how such an overloaded plane could safely be landed again. One assumes that the bombs will be dropped somewhere remote from the home field, or the fuel consumed to lighten the plane before landing.

The design of military airplanes is fundamentally controlled by military requirements, and will be specialized as these requirements are specialized. Thus we have heavy bombers of long range to carry very heavy loads, light bombers of high speed, dive bombers and torpedo planes with special features of control, interceptor fighters of extreme speed and climb but short range, and escort fighters with long range and heavier armament.

Such airplanes are not very well adapted for the economical transport of passengers and goods, yet the knowledge of the aeronautical sciences which makes them possible can be applied to the design of commercial airplanes. From the technical advances now being made in military aircraft, we may safely forecast corresponding advances in future civil aircraft for our air lines.

PROGRESS IN COMBUSTION OF FUELS

Without invading regions of official secrecy, it is evident that progress is now being made in certain aspects of aeronautical science and that one is justified in venturing some opinion as to the general nature of future technical improvement in both military and commercial aircraft.

To begin with, we must realize that the airplane is the creature of the internal-combustion engine. The gasoline engine of the beginning of our century made possible both the automobile and the airplane. Progress in the airplane has paralleled the technical development of its engine. The most spectacular improvement in the engine has followed better knowledge of the nature of the combustion of the fuel in the cylinder. From such knowledge came scientific methods for testing the octane number of a fuel as a measure of its detonation characteristics. Midgeley's introduction of tetra ethyl lead to raise the octane number of a fuel has permitted engine designers to go to higher compression ratios with consequent improved power and economy. Military aircraft must have fuel of the highest octane rating procurable; military pressure will create additional capacity for such special fuels, and will stimulate the produc-

Presented at a meeting, Dec. 31, 1940, at the Engineers' Club of Philadelphia, of Section M (Engineering) of The American Association for the Advancement of Science.

tion of fuels of even higher octane rating than the best now available. Likewise, the national-defense program is requiring engines of even greater power for take-off with large bomb loads and greater economy in order to obtain a longer radius of action. The new engines must use the improved fuels.

Obviously, our air lines will become eventual beneficiaries of the bigger and better engines and the fuel to go with them. The commercial industry could never afford to subsidize the fuel and engine development costs that are involved. With more powerful engines, the Army will develop long-range multiengine bombers and the Navy long-range multiengine flying boats. These aircraft will, of course, not be equipped for passengers, but requirements for habitability for their crews will force consideration of adequate heating and insulation, soundproofing, de-icing, radio communications and navigation, and special arrangements for substratosphere flying. For large military craft there will have to be developed suitable tires, wheels, brakes, servo controls, and many types of special navigational and radio equipment which do not now exist.

Our designers and manufacturers, as a result of their experience with the defense program, should be in an excellent position to adapt these aircraft for commercial purposes. The military aircraft may be too fast to be economical and may have unsafe take-off and landing characteristics for immediate conversion to air-line use, but their designers certainly will know what alterations are needed. The basic technical problem and one solution of it will be known. The designer will then have only to work out a new solution making use of a proved method.

AERODYNAMICS OF THE AIRPLANE

Another field in which rapid technical progress is being made is in the aerodynamics of the airplane itself. This work, done in order to obtain higher speed from the same power, is all to the advantage of the air-transport operator who must lower his costs and his fares as his business grows.

The reduction in drag by the use of smoother surfaces exposed to the air has already been mentioned. Roughness of surface is associated with the breakdown of the initially smooth laminar flow of air in the boundary layer next to a surface. This alteration of laminar flow into a turbulent regime of much higher drag is delayed if the pressure gradient along the chord of a wing is falling. Shapes of wing section in which the pressure gradient is more favorable to the maintenance of laminar flow are being studied. It is to be expected that, by the use of new wing sections made very smooth by new techniques of fabrication, substantial reductions in drag may be realized in future.

APPLICATION OF FLUID MECHANICS TO COOLING PROBLEM

One of the largest sources of wasted power or drag comes from the necessity for cooling the engines. The liquid-cooled engine must have a large radiator and the air-cooled engine must have a strong flow of air over its cylinders. Recent research has shown that the drag of this cooling air can be very much reduced if the principles of fluid mechanics are applied to the ducting system that leads the cooling air in and out of the airplane. In addition to the direct cooling of the engine, moreover, an internal air flow is required for the carburetor and the oil radiator and, if the airplane is designed for high altitudes, for the intercooler of the supercharger.

An internal-combustion engine, of course, develops power from the combustion of fuel in the air that fills the cylinder. At an altitude of about 18,000 ft the oxygen content of a cylinder full of air is only half of that at ground level, and consequently only half as much fuel can be burned in this lighter air. The power of the engine, therefore, falls off very rapidly with altitude, unless the engine drives a compressor or supercharger to supply itself with air at ground-level pressure. The supercharger heats the air adiabatically as it compresses, and the air is further heated by the turbulence and eddies created by its passage through the supercharger. To attain ground-level conditions in the cylinder, a radiator, called the intercooler, is required to cool the compressed air before it passes into the engine.

Drag caused by the intercooler means wasted power, and the power taken from the engine to drive the supercharger is also wasted as far as carrying pay load is concerned. Present efforts to improve the efficiency of the supercharger as a pump should be helpful, and very real savings can be made in the ducting of the air. An alternative solution, which saves the power taken from the engine to drive the supercharger, is obtained if the supercharger is driven by an exhaust-gas turbine. Such turbines spin faster as the airplane goes higher, and have ideal characteristics for the purpose. However, the turbine is an extremely difficult apparatus to make, since it must run in very hot gas and at very high revolution.

The national-defense program will inevitably do much to bring about technical progress in supercharging, gas turbines, and associated control apparatus which our air lines badly need when they fly "above the weather."

USING EXHAUST FOR JET PROPULSION

Another aspect of the effort to get high-speed results in belated attention to the energy of the exhaust. This is about equal to the energy developed usefully by the engine. When airplanes flew at 200 mph at moderate altitudes, the exhaust problem was merely one of disposal. If no flame blinded the pilot and no gas got into the cabin, disposal was satisfactory. At high altitude and high speed, however, it is possible to recover considerable forward thrust by passing the exhaust out through suitable nozzles. This is in effect "jet propulsion," long known to be a very uneconomical scheme at ordinary speeds. At high speeds, the jet is really effective and efficiency is of little consequence since the waste energy of the exhaust is being used. It is estimated that as much as a 10 per cent gain in effective thrust of the engine can be obtained from the exhaust. Whether commercial air lines will develop an interest in jet propulsion will depend on whether their future requirements include much higher speeds of flight.

RESEARCH IN AERODYNAMICS

Another kind of technical progress is based on research in aerodynamics. With improved wing sections, the ratio of lift to resistance to forward motion has been notably increased in recent years. This increase should make for higher speeds with the same power, but the so-called high-speed wings are not good weight carriers and would entail too high a landing speed to be practical for commercial aviation. By means of slots and trailing-edge flaps, it is now possible when approaching a landing to convert the wing temporarily to a high-lift type. Since the development of improved high-lift devices of this sort is of great importance to bombers as well as to commercial planes, we may expect military pressure to accelerate it. Wing loadings have increased recently from 30 to more than 40 lb per sq ft, and the limit is not in sight.

With higher wing loading, the length of run at take-off requires large airports, and we shall see a considerable enlargement of our American airports as part of the defense program. This will aid the extension of our already rapidly expanding civil air-transport industry.

AIR-COOLED VS. LIQUID-COOLED ENGINES

As to the importance of one feature of technical progress, even the so-called experts have been badly misled. I refer to questions about the ability of the American type of radial air-

cooled engines now universally used by our air lines. Since European engines are liquid-cooled and are used in high-speed pursuit machines like the British Spitfire and German Messerschmitt, there has been wide acceptance of the idea that this country cannot build high-speed fighting airplanes until it has liquid-cooled engines of the European type. Furthermore, since certain stripped German airplanes broke the world's speed records twice in 1939—a Heinkel in March at 464 mph and a Messerschmitt in April at 469 miles officially, and 481.4 unofficially—the momentary speeds developed have been accepted as inherent in the liquid-cooled engine used. This is an entirely false inference.

At the time that the Germans were claiming the world's speed record, moreover, American planes equipped with American air-cooled engines of similar rated power output were making a high speed in normal flight of about 330 mph while British planes with liquid-cooled engines of the same power output were credited with 360 or more miles per hour. The case for the liquid-cooled engine seemed to be very convincing. Yet it was based on a false conception of the aerodynamics of the matter. There was also an element of propaganda in it.

The test of war has shown that the German fighting planes have a real speed of about 350 mph and that their British opposite numbers make the same speed or a little more. In the meantime, progressive improvement in the installation of the American air-cooled engines has brought up the speed of our fighter planes.

The National Advisory Committee for Aeronautics in its Langley Field wind tunnel has developed means of streamlining (ducting and cowling) the American radial air-cooled engine, so that its drag can be made as low as that of the best liquid-cooled engine installation. Thus recent technical progress has enabled American airplane builders to demonstrate airplanes with larger air-cooled engines at speeds exceeding 400 mph. There now appears to be nothing to choose, as to speed, between the two types of engine when each is properly installed. This statement could have been true several years ago, but the results of research were available only recently.

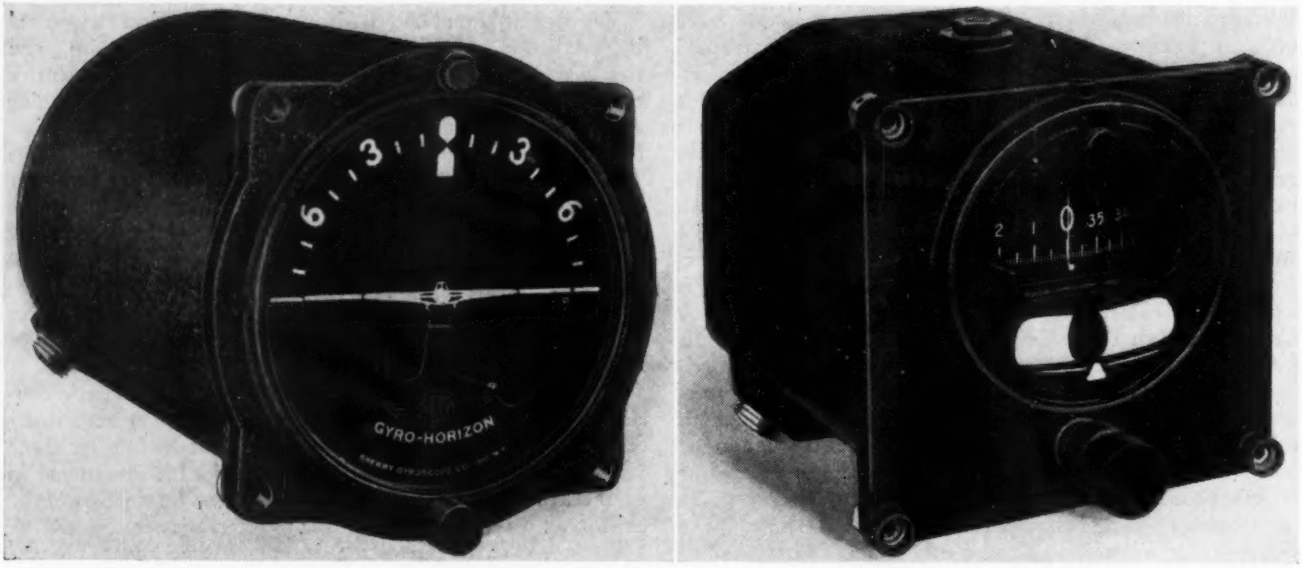
The largest liquid-cooled European-type engines now used by Germany and England develop about 1200 hp, and this year, 1941, we shall have similar engines in quantity production here. Two new types of American air-cooled engine are already developed and in production in the 2000-hp size. Nowhere else in the world are engines of such power available. The demand for armor, protected gasoline tanks, and heavier armament can safely be predicted to make the 1200-hp engine inadequate in the near future on account of the increased weight involved. Also there is always a demand in war for more speed. This country, however, can meet these demands by the development of a 2000-hp fighter to compete with the 1940 European 1200-hp plane. We have the engines, and the knowledge of how to install them for high speed.

Production for war is not like production for domestic consumption. The businessman trained in commerce may insist on "freezing" the design and going into production for three years on the same article in order to recover his investment in engineering costs. In war, technical progress on the part of the enemy can make such a three-year program disastrous.

We now have the interesting situation of a very large production program for 1200-hp fighter airplanes based on European-type liquid-cooled engines which is getting well under way at about the time our own engineers present us with two 2000-hp engines, and our scientists show us how to streamline them in an airplane installation to secure extremely high speed.

The position seems to be that we are using our great productive capacity for an immediate program of fighting airplanes that are the equal of anything known in Europe, and yet we have the potential ability to make obsolete all fighter airplanes in the world today, including our own. This position has come about by recent technical progress in engines and fuels, combined with new knowledge of the aerodynamics of air flow. When we should take advantage of this recent technical progress is a delicate question involving a balance between strategic and tactical considerations. It is the old dilemma of quantity now versus quality later and can be decided wisely only when we know whether it really is later than we think.

AERIAL VIEW OF ATLANTA, GA., WHERE A.S.M.E. SPRING MEETING WILL BE HELD MARCH 31–APRIL 3, 1941. SEE PAGES 158–159.



LEFT: THE GYRO HORIZON IS A DIRECT-READING INDICATOR OF FLIGHT ATTITUDE FOR BANK, CLIMB, OR GLIDE. IN THIS POSITION LEVEL FLIGHT IS INDICATED. RIGHT: THE DIRECTIONAL GYRO IS A FIXED INDICATOR OF DIRECTION FOR STEERING STRAIGHT COURSES AND FOR MAKING PRECISE TURNS

QUANTITY PRODUCTION *of* GYRO INSTRUMENTS

By P. R. BASSETT

SPERRY GYROSCOPE COMPANY, INC., BROOKLYN, N. Y.

THE airplane-instrument business is now about 25 years old. It is a well-established and essential branch of the aviation industry. Its development and growth is so closely involved with aviation history that it cannot be separated. Each advance in airplane or engine performance has called for new or better instruments. As the airplane became capable of long-range action and greater capacity, instruments for night flying, blind flying, and ocean navigating became necessary. Greater precision and reliability were demanded from the standard instruments. These demands have been met so satisfactorily, it has been generally conceded that American airplanes carry the best instrument equipment in the world.

This preamble sounds fine, but what has it to do with production? The answer is, Nothing, and that is the reason for including it. Before discussing aircraft-instrument production, we must understand that the background of 25 years of successful development of new instruments and perfection of old instruments has not included worries of quantity production. The main emphasis has been on designing an instrument which would function; next, it has been put in such shape that it could be manufactured in the necessary quantities to meet the moderate needs of the industry. During the past history of aviation, the necessary quantities have meant a few hundred of this and a few hundred of that. When we have spoken of "production," we have meant small quantities. With the advent of rearmament programs and the recent great acceleration of these programs, brought about by developments in Europe, demands have soared and we suddenly find ourselves talking thousands instead of hundreds.

Contributed by the Aeronautic Division and presented at the Annual Meeting, New York, N. Y., December 2-6, 1940, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

ELEMENTS OF AIRPLANE-INSTRUMENT PRODUCTION HISTORY

No matter what the rate of increase in demand for an instrument may be, its production history can usually be broken down into three phases: (1) lots of 10; (2) lots of 100; (3) lots of 1000. The "lots of 10" is the engineer's phase; he checks every instrument. Their proper functioning is his main concern. The "lots of 100" is the foreman's phase; he checks every instrument. Uniformity is his main concern; the experts are still necessary for checking the individual performance of each instrument. The "lots of 1000" is the production phase; no single person checks every instrument. Control is the main concern. By "control" is meant control of materials, control of workmanship by inspection, control of testing by specification, and general control or production planning. Planning includes the major problems of increased plant, increased machine tools, and increased personnel.

In general, these statements apply to most manufactured items. Specifically, however, no two cases are alike and the methods used in one are not applicable to another. Even within the limited field of aircraft instruments, there is no "best" method for going into production. The remainder of this paper will treat the problem from the specific point of view of gyro-instrument production. The many problems common

to most production will not be discussed. The unusual features of this product and this situation will be emphasized in the hope that some of the methods of approaching the problem may be helpful to others.

The two gyro instruments to be considered are the "gyro horizon" and the "directional gyro." They are classified as "flight" instruments. The gyro horizon indicates the attitude of the airplane. It consists of a small air-driven gyro spinning on a vertical axis. The gyro is linked to a "horizon bar" which can move universally over the face of the instrument. A small airplane silhouette is fixed to the center of the instrument face. The relation of the miniature airplane to the artificial horizon bar indicates to the pilot the relative attitude of his own ship with respect to the true horizon.

The directional gyro consists of a similar small gyro, mounted to spin with its axis horizontal, but free to turn in azimuth. It carries on the vertical gimbal ring an azimuth scale which the pilot reads against a lubber line, as he does a magnetic compass. The directional gyro does not seek an azimuth as does a compass; it merely maintains an azimuth when set. It is usual practice for the pilot to set the directional gyro to coincide with the magnetic compass and then to check it from time to time.

Together these gyro instruments give the pilot continuous indications of the three axes of the coordinate system in which he flies. They give the fundamental information for "blind" or instrument flying. They were developed originally to meet the urgent need of air-mail pilots, whose scheduled missions carried them into night, fog, and blind flying. Military flying had not then taken to the clouds. Now the emphasis has changed and military aviation has turned to instrument flying, not only for all-weather operation but even, in many cases, as preferred-weather operation. The instruments, therefore, are required on all military airplanes, large bombers, medium fighters, and small pursuits—Navy as well as Army, British as well as United States. As the programs built up very rapidly and the total numbers pyramided, there was some fear that special items such as the gyro instruments might prove to be bottlenecks. We have appreciated the responsibility of our position in being the sole source of supply for these items and for 4 years have been working on plans for meeting a possible emergency. Our chief concern has been the realization that these instruments could not be produced suddenly in larger quantities without a great deal of preparation. Neither increased space nor hiring more help can increase the production of precision instruments. To meet our problem, high-grade machine tools and skilled mechanics, trained to make the special parts, were necessary as stand-bys. The customer does not give sufficient warning to allow preparations to be made after the order is received. The length of time for delivery is generally governed by the length of time to build the airplanes. But it takes longer to build a gyro instrument than it does to build an airplane. Consequently, orders for the instruments never include margins for expansion plans; in fact, they start off with a negative time allowance. All of these considerations forced us to long-range planning.

LONG-RANGE PLANNING

By long-range planning is meant planning before the emergency and beyond the emergency. It is conceded that the present situation is abnormal and will not continue indefinitely. Yet it is not entirely new; it has happened before and may happen again. In 1917–1918, this country was woefully unprepared to meet the war emergency. During the next two years, peacetime readjustment caught us equally unprepared and the period proved to be yet more wasteful and inefficient than the war years. Out of that experience grew a plan. This was the industrial-preparedness or M-Day plan initiated by the War Department after the last war. Briefly, it consists of preparing a classified inventory of available industrial capacity, assigning this capacity to take up specific emergency armament items, and acquainting this capacity in its emergency duties by educational orders. The plan is excellent in concept and many portions of it are functioning very well. But, in practice, it has not functioned as theory calls for because of the following reasons:

The industrial facilities are not static; they are dynamic and fast-changing. The limited personnel assigned to M-Day planning cannot possibly complete the rounds before a large portion of their plans are obsolete. Many companies involved feel that the plan is theoretical and, therefore, remain uninterested in keeping the planners informed of changes. The term "M Day" has lost its significance as we have gradually accelerated our armament program in many respects beyond M-Day plans without announcing anything. Already equipping a conscripted army and well into building a vast air force, we have not discovered whether M Day is ahead of us or behind us. But the fact remains that the M-Day plan in some form is still essential and is economically the correct long-range plan. It allows the most rapid expansion and enrolls labor and supervision most rapidly. It also makes the peacetime readjustment and contraction the least upsetting. It scraps the least tools and facilities and dislodges the least labor.

Our company has been closely associated with the M-Day plan. We have seen its many advantages since its inception, and have developed a modified plan of our own. We commenced to put this plan into action in 1937; since then, it has grown into an important part of our emergency-production program. Realizing our own limitations, both as to floor space in our city building and our machine-tool limitation, we first started a survey in the city region to find available machine-tool capacity. The precision work which we required necessarily limited the list stringently, which gave all the more reason for the search, as expansion of precision work cannot be accomplished overnight as can ordinary machine work. Starting with one or two machine shops in our own locality, we gave them small educational orders. These orders involved only a few thousand man-hours.

EDUCATIONAL ORDERS FOR PRECISION WORK

We undertook the full responsibilities implied in the term "educational orders." Government educational orders are orders on which the new contractor may educate himself. This is slow and hazardous, so we adopted the system of educating our subcontractors by sending our own experts into their shops. Our methods men, shop experts and inspectors assisted the subcontractors in fitting the work to their machines, helping to train their men, modifying our jigs and fixtures to suit their conditions and assisting them in the many small troubles which new work brings. The months that followed saw a continuation of this program of preparation. In conjunction with the government M-Day procurement divisions, plant after plant was surveyed. The unsatisfactory ones were discarded. Those offering possibilities were closely analyzed and their machine-tool equipment tabulated. Small orders were placed with them and many of the problems which came up in carrying out the orders were remedied by our experts so that, upon completion, they were qualified for regular production on certain parts.

By April, 1939, just 2 years later, we were receiving 25,000 hours per month from 21 individual subcontractors. By April, 1940, we had reached 140,000 hours from 32 subcontractors. Many of these are scattered in other states and yet we supply them with methods, tooling, and shop advice on call. Our own inspectors are stationed at their plants both for first-piece in-

spection (which saves much rejection) and final inspection of completed parts. This saves much time and trouble in shipping, reshipping and explaining rejections. Our monthly subcontracted hours are still increasing and will be over 200,000 hours by December, 1940. These totals include automatic pilots as well as gyro instruments. This steady increase in subcontracting machine-hours does not mean that we are not building up our own machine facilities. On the contrary, we are now attempting to keep constant the ratio of our own machine hours to subcontracted machine hours.

Deliveries on new machines are obtained as rapidly as possible and skilled men are found to man them. With the subcontractors acting as a cushion for the rapid acceleration in production, we can proceed in orderly fashion in getting the right machines and properly trained men for our own expansion.

PRODUCTION PROBLEMS CONNECTED WITH THE GYRO

Certain critical parts of the gyro instruments are never subcontracted, but are kept under our own strict control through the entire manufacturing process. There is not time in this short paper for many technical details, but a cursory survey of a single selected part, the gyro, will show what types of special problems are involved in instrument production. The gyro is a small 14-oz brass rotor mounted on a steel shaft. Both ends of the shaft are cone-shaped and fit into 5-ball bearings. This assembly of rotor and bearings is the heart of the instrument. The rotor must be perfectly balanced and the cones and bearings must be flawless and accurate to be enabled to run for hundreds of hours at 14,000 rpm.

When production was small, rejection was a comparatively simple way to get the necessary quality; 80 per cent rejection in certain materials or finished parts was not unknown. But, with quantity production, such methods cannot be tolerated. If the supplier cannot meet the specifications, we must go to his source and work with him to get the control or the selection necessary. For example, it has been our practice in small-quantity production to purchase an SAE steel for special ball-bearing parts in small quantities from jobbers who could supply us direct from warehouses. The variations in analysis, in heat-treating requirements and particularly in cleanliness, involved in this system, resulted in a considerable percentage of rejections of finished parts; so high, in fact, that this could not be tolerated even in limited production. Therefore, an incoming inspection was instituted in which each bar or a large proportion of bars was subjected to a macroetch, to microscopic examination for inclusions and to hardenability tests. This resulted in a considerable reduction in rejections.

With the larger quantities involved, we have had to go yet further. We are now purchasing from the steel mill an entire heat or such portions of a heat as may be acceptable. For this purpose, our metallurgist is sent direct to the mill, selecting suitable billets and marking them for further reduction to bars of various sizes for our use. By this means rejections have been reduced to a minimum.

In the production of the special bearing parts, for which the steel mentioned is used, all finishing operations such as lapping and polishing were performed by hand. As a result, the fatigue of the operator, the manner in which he performed his functions and other variables produced a wide variety of results, even when the utmost care was exercised. Automatic machines were designed and built whereby the lapping time per unit was reduced from 45 to 15 min. This automatic machinery removed the human factor except for one item, which was the lapping compound used in production. A long series of tests has resulted in a compound produced under laboratory control, and the uniformity of results has been greatly increased. Constant work on the improvement of material for laps in an endeavor to increase their life and again improve uniformity has been carried on.

The rotor wheel and shaft assembly must be carefully balanced dynamically to eliminate vibration. This operation was formerly done by individual operators, working with selected bearings, and carefully balancing by a trial-and-error system. The residual out of balance was detected by feel. The operation took an average of 3 hr per rotor, and the results again depended upon the personal equation to a great extent. The operators, however, became so skillful that, by feel, they could do a better balancing job than any dynamic, balancing machine on the market. But the process was too slow for quantity production. We, therefore, undertook our own study and designed a new type of automatic balancing machine. This development has been disclosed in a previous paper.[1] Upon the completion of this machine and the installation of the first units in the rotor-assembly department, each of which turned out a rotor every 15 min, we considered that this problem was completely solved.

SOLVING ROTOR-BALANCING DIFFICULTIES

It was not long, however, before it was discovered that these rotors did not stay in perfect balance. Furthermore, when they were put back on the balancing machine, they had apparently gone out of balance in a different spot. The problem was worked on for quite a while before the answer was developed. It is our practice to oil the bearings before placing the rotor in the balancing machine. Occasionally, a small amount of oil would get on the rotor itself, but it had always been assumed that the high rotational speed of the rotor would throw it off. Apparently, even the residual oil film was enough to indicate unbalance. It was found that a perfectly dry rotor would always read the same on the balancing machine, whereas, one with a slight amount of oil would show erratic results.

In addition to this, we had always painted a spiral or scroll on the rotor which would enable us to determine stroboscopically its operating speed. Discovering the difficulty with oil turned our attention to the amount of paint being applied, and this led to the development of a rubber stamp which places a very thin film of special ink on the rotor in a uniform amount in place of the old hand painting. The uniformity of results from this method has now enabled us to eliminate the hand inspection operation following the balancing. These details have been mentioned to show the high degree of precision which is necessary to obtain satisfactory rotors.

In terms of ounce-inches, some figures may be of interest. A good smooth balance of a commercial rotor of equivalent size will be within 0.001 oz-in. This is about the limit of the avail able commercial balancing machines. Our own rotors, because of the precision with which they are made, run about this amount of unbalance before we start our balancing operation. We, therefore, start where others leave off. With our present balancing machine, we can obtain an accuracy of 0.00001 oz-in., which may be termed "velvet smoothness."

PRECISION PARTS SPEED UP ASSEMBLY

Up to this point, only the manufacture of parts has been discussed. We place great emphasis on the precision of parts and their careful inspection in order to avoid as much trouble as possible in the assembly operation. Where assembly is accomplished by file and fit, or by selection of individual combinations which go together, too great personal skill is necessary. This method is not infrequently used by instrument companies, but it results in inflexibility and thereby makes expansion difficult and line production impossible. Our extreme care in

(Continued on page 124)

[1] "Dynamic Balancing of Small Gyroscope Rotors," by O. E. Esval and C. A. Frische, *Electrical Engineering*, vol. 56, 1937, pp. 729–734.

Recent PROGRESS *in* AERONAUTICS[1]

I—Progress in Aerodynamics

By CHARLES TILGNER, JR.

GRUMMAN AIRCRAFT ENGINEERING CORPORATION, BETHPAGE, L. I.

OWING to the unsettled conditions prevailing throughout the world today, most recent developments in aerodynamics are on a restricted or confidential basis and cannot be disclosed. Aerodynamic knowledge during 1940 has advanced in an orderly fashion. Additional data have been obtained on the major problems, but nothing appeared which could be classed as startling after the results had been thoroughly analyzed.

As the speed of airplanes increases, compressibility becomes an ever more important factor. Much work has been done in high-speed tunnels on this interesting subject, but it is only recently that an attempt has been made to correlate this with flight research.

At low speeds and low altitudes, the power available from exhaust-jet propulsion is negligible, but at speeds above 350 mph and at altitudes above 20,000 ft an important gain is indicated. This may be accomplished with no reduction in engine horsepower supplied to the propeller; however, the optimum gain at present seems to be with a nozzle which reduces horsepower slightly. The amount of choke required depends upon the speed and altitude at which it is desired to operate at maximum efficiency.

With respect to high-lift devices, interest still seems to be centered on the trailing-edge flap. Most of the recent developments seem to be on flaps of the slotted type. The effect of slot shape, size, and location, and of multiple slots has been investigated. They show promise of still higher maximum lifts with the possibility of varying the drag to permit using the flaps for take-off as well as landing. Needless to say, the motions become more complex and will require considerable ingenuity to effect a reliable mechanism.

Along with the effort to obtain better high-lift devices, attempts have been made to extend the flap over the full span of the wing by substituting other devices for the conventional aileron. Several interesting methods of obtaining the necessary rolling moment have been evolved, but none, as yet, has proved as desirable as the universally employed hinged trailing-edge surface. It is possible that considerable advance along these lines may occur in the near future.

Many opinions have been voiced on the proper way to combine a wing and a fuselage. Adverse interference between these bodies is often present. Many tests have been made of the effect of fillets on juncture interference with varying success. Now attempts are being made so to combine the bodies that fillets are unnecessary. Closely correlated with this are efforts to determine the optimum fineness ratio on streamline bodies where disturbances that weaken the flow exist near the forward portion of the body. It has been found in some cases that the fineness ratio must be practically doubled.

Because of the multitude of arrangements possible with liquid-cooled engines, submerged installations of air-cooled engines have been proposed, and the advantages and disadvantages of such an arrangement have been given consideration. As a result of this study and of the increased use of supercharging, the subject of duct design has become important. Numerous shapes both of duct entries and of exits have been investigated.

The question was raised last year: "What will be the effect of the war in Europe on aerodynamic development in 1940?" The main result appears to have been an increase in the money available for research, but a decrease in the information generally available. All developments which show promise become closely guarded secrets, with the result that it will be several years before the advances in 1940 can be truly evaluated.

II—Progress in Aerodynamics

By VERNON OUTMAN

THE GLENN L. MARTIN COMPANY

PROGRESS in any line of endeavor that is connected with national defense has naturally been influenced by present-day conditions. The field of aerodynamics has been affected in several ways. First, practically all technical information is considered confidential and withheld from publication. Second, owing to the time element caused by the demand for production, design decisions must be made without much time for development or refinement. This will tend to restrain aerodynamic advancement to some degree, although the third and most important effect, the demand for increased performance, will tend to accelerate progress along this line.

In the search for higher speeds, numerous experimental research programs have been initiated. One investigation showed a large portion of the total airplane drag to be caused by scoops, vents, leaks, and other protuberances. Of course, each appendage was installed for a definite purpose, such as ventilating or cooling, and some means of accomplishing these purposes, but with minimum drag increase, must be found before large improvements can be realized.

The profile drag of wings, as affected by surface texture, has been given further study and measurements were made on airplanes in flight. The general statement that using flush rivets in the forward 30 per cent of the wing removes substantially all of the rivet drag, has been found to require modification. Rivets, ahead of the 30 per cent point, may cause an early transition and thereby increase the drag considerably, but the form drag is present at any station on the wing. Service wings usu-

[1] Progress Report of the A.S.M.E. Aeronautic Division presented at the Annual Meeting, New York, N. Y., Dec. 2–6, 1940, of The American Society of Mechanical Engineers.

ally have larger rivets between the spars than on the leading-edge section, and in one case, when the rivets on the front portion of the wing were removed, no increase in high speed could be measured. Aileron or flap hinges, pitot-tube supports, anchor rings, rivets, and surface waviness are responsible for a large increase in wing drag, and extreme care must be taken to obtain an aerodynamically smooth wing.

The laminar-flow airfoil which was mentioned in last year's report is still under development. One reason is the necessity of obtaining extreme surface smoothness before the advantages of the section can be realized. Also, other difficulties must be overcome. This development opens new possibilities for increasing performance and it is hoped that practical solutions to the various component problems will soon be found.

Another means of reducing wing drag, besides improving the wing in quality, is to reduce it in quantity. This may be done and still keep the same landing speed by the use of more efficient flaps. The slotted trailing-edge flap has been developed to a high degree of efficiency and is being used in a number of designs.

In the rush to provide the designer with ways and means of improving the airplane, little attention is paid to the problem of aiding him to predict the performance. The only reasonable method available at present is to test a model in the wind tunnel and obtain the airplane drag upon which the performance may be based. However, owing to scale effect, small parts which cannot be duplicated on a model, cooling drag, the effect of slipstream, and changes in propeller efficiency, the results from the wind tunnel must be compensated. This is done by applying an increment or percentage, depending on results obtained on a previous similar model. This is not very accurate, and the flight performance is often surprisingly different. Research should be initiated to provide a correlation between flight and wind tunnel to allow a more accurate prediction of performance.

Research is under way on more rigorous methods of analyzing propeller performance. Until recently, little attention was paid to blade design, but now the demand for greater speeds calls for higher efficiencies. New shapes and airfoil sections are being studied and tested. Cuffs, which cover the round shanks of the blade and are primarily to improve cooling, have been found to improve the efficiency. The advantages of spinners have not been established in all cases. The effect of high tip speeds is still considerably in doubt and progress in this direction must await better research facilities.

While the emphasis has been primarily on speed, the flying characteristics of the airplane have not been completely forgotten. One reason the designer did not improve the handling qualities of the airplane is that he had no quantitative requirements to meet. These criteria will soon be available. A research program is under way in which data on a number of airplanes are to be obtained and correlated with the pilot's reaction. This will provide information on the airplanes now considered satisfactory and methods will have to be found to make sure that new designs meet the requirements. After the knowledge of quantitative flying characteristics becomes more tangible, the designer will probably be called upon to improve them.

One incidental result, which is not exactly aerodynamic, came out of this research program. This was the fact that on large airplanes, the deflection of control cables greatly reduced the total effectiveness of the control. Steps are being taken on this type of airplane to eliminate this fault, and also to keep the control-system friction to a minimum.

The quest for higher speeds and more range has resulted in changes which have detracted from the handling characteristics of airplanes. One instance is the use of wings with higher taper ratios to reduce weight. This has increased the tendency toward tip stall, and various modifications, such as tip slots, have been used to prevent it. Tip slots reduce the performance; and other means of avoiding tip stall which do not increase the drag are being sought.

Highly loaded airplanes with stalling characteristics that are near the unsatisfactory limit increase the necessity for the study of spinning characteristics. Systematic research has progressed and a number of parameters have been investigated. Some attention has been directed toward the spinning tendencies of large airplanes. Here, the problem is to stop a spin in its early stages before it becomes fully developed. The latter problem still needs thorough investigation.

One very important development is the expansion of the research facilities of the N.A.C.A. The construction of new laboratories on the West Coast will undoubtedly influence aerodynamic progress in the future.

Although the emphasis is, at present, on higher speeds for military aircraft and a large portion of the aerodynamic improvements are developed for this purpose, most of them will eventually benefit civil aircraft as well. Also, increased production will permit the financing of more research work and progress in aerodynamics should be accelerated even more in the future.

III—Progress in Aviation Accessories

BY R. P. LANSING

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AFTER a period of what might be termed one of outstanding radicalism in developments, we now are in a period of enforced simplification, brought about by necessity resulting from quantity production.

The greater portion of production airplanes carry fewer different types of accessory equipment. Standardization and simplicity prevail.

Hydraulic mechanisms have been simplified. Electrically operated mechanisms have come into much more general use. Direct-current power supply has dominated over alternating-current as a major power supply, except for the operation of remote-reading instruments.

Auxiliary engines are in production, but limited to the larger plane classifications, while generators of high capacity output are now filling the intermediate requirement.

Injection carburetors have established themselves by proving their superiority over previous types with fuel injection, with possible use of safety fuel in the immediate offing.

Magnetos have been perfected for altitude operation with reductions in weight and bulk, while shielding and spark-plug development have by necessity made rapid strides to keep pace with the rapid advancement in the higher-powered-engine development.

In 1940 the continued search to eliminate hazards and reduce weight led to greater use of remote-reading instruments. This development occurred in the direct-current as well as the alter-

nating-current field. Dual indication on one dial conserved instrument space and weight.

Remote-reading compasses took a step forward in the development of instruments suitable for use in planes and surface ships. Several variations were completed in which could be found such features as true heading, an improved type of compensation, and course transmission. These compasses are of the magnetic and earth-inductor type. Because the transmitter can be located at the most favorable spot in the plane, as far as magnetic field and vibration are concerned, better indications are obtained.

Development of the automatic radio magnetic compass brought out an instrument by which the pilot could fly toward or away from a radio station, regardless of cross wind.

IV—Development in Aircraft Power Plants

By A. T. GREGORY

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OUTSTANDING in the progress of aircraft engines in the last year has been the development of the air-cooled radial engine of 2000 hp. Two engines are now available in this horsepower class, one produced by Wright Aeronautical and one by Pratt and Whitney.

The Wright engine is an 18-cylinder, twin-row engine developing 2200 hp. This engine has a displacement of 3350 cu in. and weighs 2450 lb, or 1.1 lb per take-off horsepower.

The Pratt and Whitney engine is also an 18-cylinder twin-row radial engine developing 2000 hp. This engine has a displacement of 2800 cu in. and weighs 2300 lb or 1.15 lb per take-off horsepower.

A new record has also been achieved in the single-row radial class during the last year. The Wright 9-cylinder *Cyclone* G-200 engine has successfully passed its model test with a take-off rating of 1200 hp. This engine has a displacement of 1820 cu in. and weighs 1310 lb or 1.09 lb per hp. Normal rating of this engine is 1000 hp at a crankshaft speed of 2300 rpm at an altitude of 6900 ft.

It is interesting to note that there appears to be no particular advantage of the large twin-row engine over the single-row radial engine from a specific-weight standpoint. Weights of each type have been brought close to what appears at present to be an asymptote of one pound per horsepower.

With the Allison 12-cylinder liquid-cooled engine now in production, a new engine type has been added to the list of service engines during the last year. This engine type permits the airplane designer to make finer streamline structures which result in higher speeds without increased horsepower. This design of engine has not been built heretofore in sufficiently large quantities to require the extensive tool, gage, and jig equipment that became necessary when the prompt production of thousands of engines became part of our national-defense program. This expansion necessitated an enormous expansion of both personnel and facilities. Personnel have been drawn largely from the experienced engineering and production man power available in the automotive industry. In order to insure continued and satisfactory operation of a new type of engine without the benefit of years of service experience on the engine, a program was initiated for continually proof-testing parts and completed engines to provide the knowledge and experience that would in turn be correlated with actual normal and accelerated airplane flight testing.

Another new-type engine to reach the production stage in the last year is the in-line air-cooled engine in the 500-hp class. The Ranger inverted V-12 engine is now available with a take-off rating of 520 hp and a normal rating of 450 hp at an altitude of 12,000 ft. The normal cruising output of 300 hp is maintained up to an altitude of 15,000 ft. While actual service experience on this model has been comparatively small, a great deal of experience has been accumulated on the Ranger six-cylinder engine, which although unsupercharged, embodies many of the features of the 12-cylinder model. The six-cylinder engine is likewise an inverted, in-line, air-cooled engine with a rating of 175 to 200 hp at 2450 rpm. This engine is now in production in large quantities for Army trainers. Although it is a naturally aspirated engine with a single carburetor for all six cylinders and only one intake valve per cylinder, the use of ramming-type manifolds has resulted in the development of a maximum brake mean effective pressure of 156 psi at a crankshaft speed of 2050 rpm, which is the take-off and climbing engine speed with a fixed-pitch propeller.

DEVELOPMENTS IN LIGHT-PLANE ENGINES

Following the trend in the higher-horsepower class, light-plane engines are also distinctly moving into higher horsepower brackets. There appear to be no new engines in the 50-hp class, rather engines in this class are moving up into the 75- to 100-hp, and even to the 130-hp classes. Three distinct methods are being followed in increasing the horsepower of these engines. One is the development of reduction gearing to permit running the engines to high speed. Lycoming has done considerable work along this line particularly with reference to the problem of torsional vibration, but other companies are also working on the problem. Second, in a few cases cylinder bore and stroke have been increased to obtain an increased displacement and thus increase the rating for the same engine speed. The third method of increasing horsepower has been the addition of more cylinders to the engine. Most light-plane engines have been of the four-cylinder, horizontal, opposed type. During the last year, however, Franklin has brought out a six-cylinder opposed engine which is a development of this four-cylinder model. The cylinder assembly, connecting rods, valve lifters, main bearings, connecting-rod bearings, and gear trains are absolutely interchangeable with the four-cylinder series. In addition, the tooling of the engine is such that either the four- or six-cylinder crankcases go through the same production fixtures.

In the case of the Franklin engine, the same tooling and general design permits the use of engines for either the aircraft or commercial field simply by certain changes in the material specifications. For example, for commercial work the crankcase is cast iron and the crankshaft is 1040 steel, Tocco-treated.

EXPANSION OF AIRCRAFT-ENGINE PRODUCTION

While not all aircraft engines may have achieved higher horsepower ratings during the last year, practically all have undergone large-scale development for the purpose of improving them from a production standpoint or for improving their reliability. Furthermore, the demands for large-scale production of aircraft engines have been so great that engine plants have more than doubled in size during the last year, and current

expansion projects are under way which will bring the total capacity during the coming year to about four times what it was a year ago. Since the total monthly engine production reported for the month of September, 1940, was up to 2400 engines per month, it is to be expected that total engine production may reach 5000 units per month in another year.

With this expansion of the production facilities of engine-manufacturing plants, two distinct trends are noted. More and more engine parts are being produced by parts manufacturers. This results in bringing many new factories into the industry and actually in still larger expansion of engine-manufacturing-plant capacity than is indicated by the foregoing figures. Parts fabricated under subcontract consist mainly of small assemblies and steel parts, such as shafts, rods, and gears.

Another trend in this expansion has been geographic in the location of manufacturing plants at new centers of production. The outstanding example of this movement is the new plant of the Wright Aeronautical Corporation near Cincinnati, Ohio. Other aircraft-engine plants will be located also through the Middle West as soon as some of the automobile companies, notably Ford and Packard, complete their present plans to enter this field.

DEVELOPMENTS RELATING TO AIRCRAFT ENGINES

There has been considerable discussion during the last year regarding variable gear reduction for propellers. While such a device would greatly complicate the engine and add considerable weight to the engine, it offers outstanding improvement in over-all airplane performance, particularly for very high-speed, high-altitude airplanes. Relatively high rotational velocities are required for take-off so that the propeller pitch does not become excessive at low air speeds. But at high airplane speeds and high altitudes the forward component of the propeller tip speed becomes so great that the rotational velocity must be reduced to hold the tip speed within permissible limits.

There has been considerable activity in the field of aircraft fuels. A great deal of work has been done with the objective of obtaining still higher-octane fuel. Simultaneously work has been in progress on the determination of new means for rating aircraft-engine fuels.

An extensive investigation was carried on by the field-engineering organization of the Wright Aeronautical Corporation to determine the factors and conditions controlling the formation of ice in the induction system of aircraft engines. Means were studied for quickly and effectively removing such ice after its formation. The results of this study were published and circulated among the industry and government agencies to stimulate further research on this problem.

Further progress has been achieved in the mounting of aircraft engines, particularly radial engines. The principles of "dynamic suspension" have been widely discussed and applied in a number of installations with outstanding results. In connection with the increased use of in-line engines of both air- and liquid-cooled types, it is interesting to note that in many installations these engines are bolted solidly to the mounting frame with no rubber at any point between the engine and the airplane structure. The smoothness of these engines has been such that no unpleasant or harmful vibrations are transmitted to the airplane structure as a result of this type of mounting.

Considerable progress has been made during the last year, particularly at Allison, on the development of extension shaft drives and the analysis of the vibration problems connected with them.

Much interest has also been directed toward obtaining higher altitude ratings by improving supercharger efficiencies and by the development of two-speed and two-stage drives.

V—Developments in Meteorology

By GEORGE F. TAYLOR

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METEOROLOGY has been developing at an accelerated rate for a number of years. The last two decades, in fact, have witnessed what has amounted to a nearly complete revolution in many aspects of meteorological thought and technique. Both theoretical and practical phases of the science have been affected by this important and rapid growth.

Recently, the war in Europe has greatly influenced the meteorological situation in the United States, as well as internationally, since it has resulted in the almost complete absence of daily synoptic weather reports from more than one third of the northern hemisphere. This has greatly curtailed research on long- and medium-term forecasting which require rather complete weather charts covering most of the northern hemisphere. Furthermore, the war has greatly reduced the output of scientific articles on meteorology from Europe, and has rendered their diffusion through the medium of scientific journals slow and uncertain.

The most striking effect of the war on meteorology, however, has been to demonstrate with the utmost clarity that weather in very many cases holds the key to the success or failure of modern military operations, and that accurate forecasting may often prove to be a most potent weapon in nearly every phase of warfare. This recognition of meteorology's important piace in the conduct of war has actually resulted in greatly accelerating its growth in both neutral and belligerent countries.

Partly because of the war, perhaps, no particularly striking theoretical advances have been achieved during the last year. Rather, a marked tendency has appeared to apply as fully as possible the theory and technique already developed to practical use, and also, as a direct result of war conditions in Europe, a vigorous program for the training of a large number of competent forecasters has been put into effect in the United States.

The United States Weather Bureau has been actively engaged during the last five years in a comprehensive program of educating its personnel in the latest modern technique. This program is beginning to show gratifying results in a steadily increasing service to the public. Forecasts are now being given much wider dissemination, and their reliability is constantly increasing. The enthusiastic acceptance of the new automatic telephone weather service in many large cities is but a single example of the increased popular interest in weather forecasting.

A greatly increased demand for specialized meteorological information has sprung up recently in many diverse fields, resulting in a corresponding increase in the number of workers in the general meteorological field.

Two important new institutions of advanced meteorological training and research have been founded during the last year, one at the University of California at Los Angeles under the

(*Continued on page 116*)

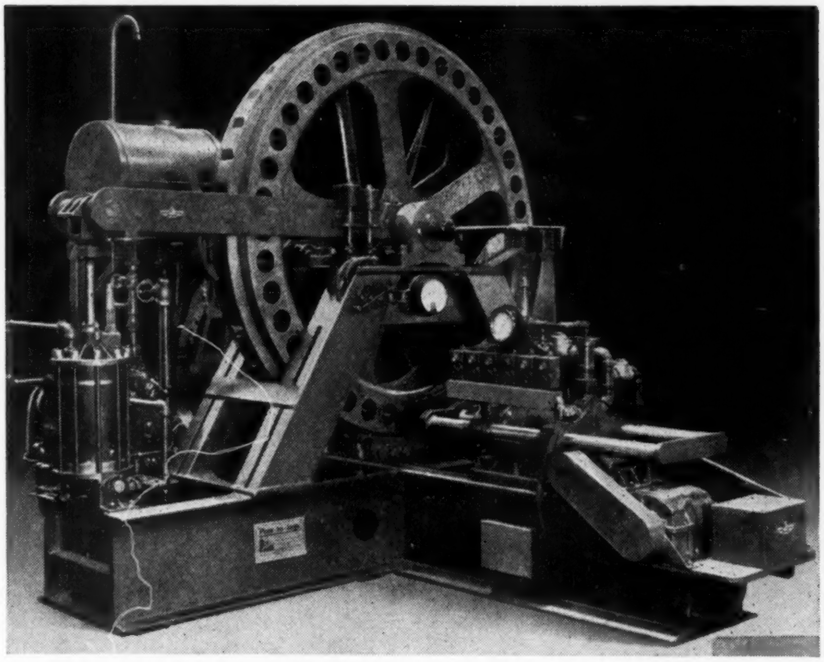


FIG. 1 A SUCCESSFUL WOOD-BRIQUETTING MACHINE

The MECHANICAL DEVELOPMENT *of a* WOOD-BRIQUETTING MACHINE

By R. T. BOWLING

CHIEF ENGINEER, WOOD BRIQUETTES, INC., LEWISTON, IDAHO

FOR many years, the lumber industry has been interested in making useful products from its otherwise waste materials. Recently this has become yet more desirable because of the increase in a type of waste quite difficult of disposal.

Until about 1920, lumber manufacturers were not called upon to remanufacture their product to any great extent. Most of the plants where lumber originated shipped much of their lumber rough. Today, this has all changed, and now most lumber shipped from lumber plants is surfaced and remanufactured into numerous items. This large amount of surfacing and remanufacturing has resulted in the development of quantities of shavings, sawdust, edgings, and trims. All this waste is dry, hence, the difficulty in its disposal. Waste of this type is light in weight, large in volume, and its rate of combustion difficult to control when burned in the average boiler furnace.

It was the large surplus of dry waste at the Clearwater plant of Potlatch Forests, Inc., Lewiston, Idaho, which caused officials of the company to consider ways and means of turning this waste into some useful product. In 1929 it was decided to attempt production of a wood fuel briquette. This appeared to be the most practical form of product in which this waste might be utilized.

The thought of making a fuel briquette of this type of waste was not new. Investigation in this field disclosed the fact that a number of concerns had worked on this particular problem and that several machines had been built for this purpose. Upon examination of the briquettes manufactured by these machines it was evident that they lacked many qualities of an acceptable product.

A study of the methods used in the attempt to make wood briquettes indicated that the correct methods had not been developed. The methods used were the conventional ones of impact and direct pressure. Experiments conducted on both methods readily proved that the desired quality of briquette could not be produced with either, therefore, an entirely new process required development. An understanding of the structure of wood and its action under pressure of one kind or another, with and without heat was the basis upon which the new process was created.

Wood is a fibrous material made up of numerous cells, each

Contributed by the Wood Industries Division and presented at the Fall Meeting, Spokane, Wash., September 3–6, 1940, of The American Society of Mechanical Engineers.

of these cells having walls and a cavity. The actual wood substance in a piece of soft wood is only one third of its volume. From this it may be seen that wood is a resilient, elastic material. The mere pressing of this material is not sufficient to retain it in a pressed state.

REQUIREMENTS FOR SATISFACTORY BRIQUETTES

Experiments clearly indicated that pressure, heat, moisture, and cooling would be necessary in the process of making a good wood briquette. Pressure, applied gradually and continuously, was required to reduce the volume of the material and increase its density to that of practically a pure wood substance. Heat had to be applied in such a manner as to bring every particle of wood up to approximately the same temperature, in order to bring out the natural binding materials in the wood to bind the particles together. Moisture in sufficient quantity and well distributed throughout the mass of material being pressed was essential to help form the binder. After pressing and heating, the mass had to be cooled in a manner to set the binding material, before the briquette could be released.

It was concluded from experiments, comparable with those of the past that, if wood material was to be made into a dense self-binding briquette, the material must be pressed in small quantities at one time under great pressure; that the pressure must be continuous and gradual from the time pressure is first applied to the loose material, continuing until it is pressed into its final state; and, further, that after the material is pressed into its final density, it must be held in this state until cooled.

After reaching these conclusions, the problem then was to design a complete machine to carry out the process.

The original machine consisted of the means for pressing material gradually and continuously in the form of a tapered pressing screw, a die, or series of dies in which to form and cool the briquettes, and a yielding pressure control which governed the density of the briquettes. Briquettes could be made with this machine, but not consistently or to the desired density at all times. The theory of pressing, holding, and controlling was correct, but the quantity of fuel being pressed at a given time was too great to obtain the desired density. The problem then was, in some way, to press the material yet more by this gradual continuous method. A means to this end was worked out in the form of a tip forming head which was attached to the pressing screw. The development of this device was the final solution in the practical production of wood briquettes.

BRIQUETTE-FORMING MACHINE

The wood-briquette machine, as finally developed, consisted of such essential parts as the pressing screw, the tip forming head, the pressing-screw shaft bearing housing, the pressing screw and tip forming-head housing, the dies, die wheel and die-wheel indexing mechanism, and the yielding-pressure-control mechanism.

Reference to Fig. 2 will identify each of these essential parts, and their functions are herewith described. The pressing screw performs two functions, that of receiving material from the source of supply and of pressing this material through the first stage of compression. Note that the screw is tapered; therefore, as the material is moved forward, it is pressed into a constantly decreasing space. The space directly ahead of the screw and up to the rear side of the tip forming head is the first stage of compression. It is the function of the pressing screw to keep this space full of tightly compressed material.

The function of the tip forming head is to take material from the first stage of compression, feed and press it into the second stage of compression. The tip forming head is designed with a cam face on both its front and rear faces. At the high point of the lead on the rear face, a slot is cut diagonally through the head; this slot enters the front face of the head at the low point of the lead. Since the high point of the lead on the rear face of the head forms the start of one side of the slot through the head, it is, therefore, a cutting edge by which material may be sliced from the mass of material pressed in the first stage of compression. The tip forming head is supported by a spindle. The spindle, being attached to the pressing screw, rotates with the pressing screw. When material has been pressed in the first stage of compression, and is tight against the rear side of the head, it is then cut off in a continuous layer and fed through a slot to the front face of the tip forming head, where it is pressed to its final density by the cam face on the front side of the head. The material is thus pressed into the second stage of compression in the form of continuous spiral layers.

The die or series of dies in the die wheel are the molds in which the compressed material is formed to the desired length for cooling. The object of a number of dies is to provide a means of holding the material in the compressed state a sufficient length of time to cool, and to obtain, as nearly as possible, a continuous operation of the machine.

The yielding control pressure performs the function of controlling the density of the briquette as it is formed. This yielding pressure is obtained by means of a hydraulic cylinder. Pressure from the piston rod of this cylinder is transmitted against the briquette as it is formed through the medium of the completely cooled briquette which is ready to be removed from the die. Pressure is built up in this cylinder by the formation of a new briquette, the cooled briquette being pushed out of the die against the cylinder rod and piston in the cylinder. The cylinder back of the piston is always full of oil, therefore any movement of the piston toward the end of the cylinder will build up a pressure if all outlets from the cylinder are closed. This is the case except that pressure is built up against an automatic relief valve. This valve may be set at any pressure which will insure the desired density of briquette. Since the formation of a briquette is at a constant rate at a given pressure, the counterpressure built up in the yielding-pressure-control cylinder will vary with the speed of formation of a briquette.

In the formation of a briquette, the yielding pressure continues during the formation until the desired or standard length is obtained. When this length is obtained, the pressing screw stops automatically. At the same time, the index mechanism starts operating and indexes the die wheel one position. At a position about one half the movement of the index arm, the mechanism on the yielding pressure control is energized, which releases pressure in the cylinder. By means of a suitable mechanism, the piston rod of this cylinder pulls away from the end of the cooled briquette which has just been removed from the die and allows it to drop by gravity out of alignment with the rod and die. At the end of this stroke, which is just sufficient to allow the briquette to fall out of line, the mechanism is automatically reversed, permitting the piston rod to be moved forward until it is in contact with the face of the die disk, which is also the end of the next cooled briquette to be removed from the die. At this point of contact of rod and briquette, the pressing screw is started automatically, thus beginning the formation of another briquette. This cycle is completed over and over in the process of making briquettes.

STANDARD BRIQUETTES PRODUCED

The standard briquette, as made with this machine, is $4^1/_8$ in. diam and $12^3/_4$ in. long; its weight is 8 lb; the density is 1.3 for the average briquette. For special purposes, if desired, the material may be pressed to a density of 1.4 which is approximately that of bakelite.

In the formation of a briquette, the material is pressed at the rate of 7 cu in. per sec. However, this does not mean that 7 cu in. is pressed in 1 instant. As stated, the briquette is $4^1/_8$ in. diam which is the size of the tip forming head. The pressing screw and forming head rotate at a speed of 270 rpm or 4.5 rps. Inasmuch as the material is fed through the head and pressed by the head in continuous spiral layers of material, this 7 cu in. is pressed in a thin layer of material approximately $^1/_8$ in. thick over an area of 60 sq in., in 1 sec.

Thus, it may be seen that, in the case of a briquette made by this process, only a small quantity of material is under extreme pressure at any one instant. The amount of pressure used is not all in one direction. By reference to Fig. 2, it may be observed that the pressing screw is tapered and that it rotates in a tapered housing. The screw compresses the material into a tapered cylinder, thereby decreasing its volume and increasing its density very rapidly. This action results in heavy thrust loads against the screw and its supporting shaft. This total pressure is normally about 165,000 lb. The counterpressure of the yielding-control-pressure cylinder varies considerably; however, the minimum total pressure in making a briquette is 15,000 lb and the maximum 25,000 lb. This pressure is held against the briquette as it is formed; therefore, since the material is formed by the tip forming head through a slot which has an area of only 1 sq in., the counterpressure on the material, as it is formed, is from 15,000 to 25,000 psi.

Briquettes made by this process are entirely self-binding. Just what the binding material consists of has not yet been determined. It is a known fact that the binding material is not pitch, as those wood materials containing little or no pitch make the best briquettes.

PROBLEMS ENCOUNTERED IN DEVELOPING MACHINE

The mechanical problems encountered in the development of this machine were many, i.e., problems of types of materials, strength of materials, new equipment, and controls. The machine is now a combination of electrical, mechanical, and hydraulic equipment.

The essential parts of this machine had to be developed independently of any existing equipment. If briquettes were to be made by the theoretical process we had evolved, as a result of experimenting with old methods, then the various parts must be developed without the assistance of any previous research in connection with this theoretical process.

Since the pressing operation is the most essential in making wood briquettes, it was decided to use a mechanical means rather than steam, pneumatic, or hydraulic pressure for compacting the material. The mechanism adopted is a tapered screw, the object of which is to maintain a continuous pressure on the material. This pressing screw is constructed in a manner similar to many screw conveyers and screw feeding devices. Most screws for handling materials are used solely for conveying and in very few instances are they used also for conveying and compacting.

This feeding and compacting screw, to be used for compacting wood particles to a density suitable for a wood briquette, differs somewhat from the ordinary screw, although the principle is much the same. No set of calculations was or could be correct for the design of a screw for this purpose. About the only way it could be developed was by trial and error. The present screws are 8 in. diam at the large end, $10^1/_4$ in. long and tapered 4 in. per ft of diam. The lead and depth of thread vary with the type and specie of wood being pressed; for example, white pine requires a 2-in. lead and $1^1/_4$-in. depth of thread. The angle of all threads, regardless of pitch, is 15 deg. All threads are cut right hand, consequently, for them to press material forward they must rotate in the counterclockwise direction. Material used to make pressing screws is 3140 chrome nickel. The entire surface of the screw from the small end and back two threads is surfaced with No. 1 Stellite or other hard-surfacing material.

RESULTS OF COMPRESSING MATERIAL

The ratio of compression of the material made into a wood briquette is approximately 10 to 1. About 60 per cent of the total compression takes place in the pressing screw and space ahead of the screw which goes to make up the first stage of compression. The remainder of the compression is accomplished with the tip forming head.

It has been explained that wood is an elastic, resilient material; therefore, when such material is forced through a tapered cylinder by the screw, it decreases in volume and increases in density and, consequently, expands against the side walls of the cylinder, thereby creating a frictional resistance to the rotating motion of the screw and the forward flow of material through the screw. From this, it is evident that the screw must be designed to compress the material to the desired density only; otherwise, the frictional load may become so great that material in the screw would rotate at the same speed as the screw and would fail to feed material forward as intended. A great amount of experimental work was required to determine

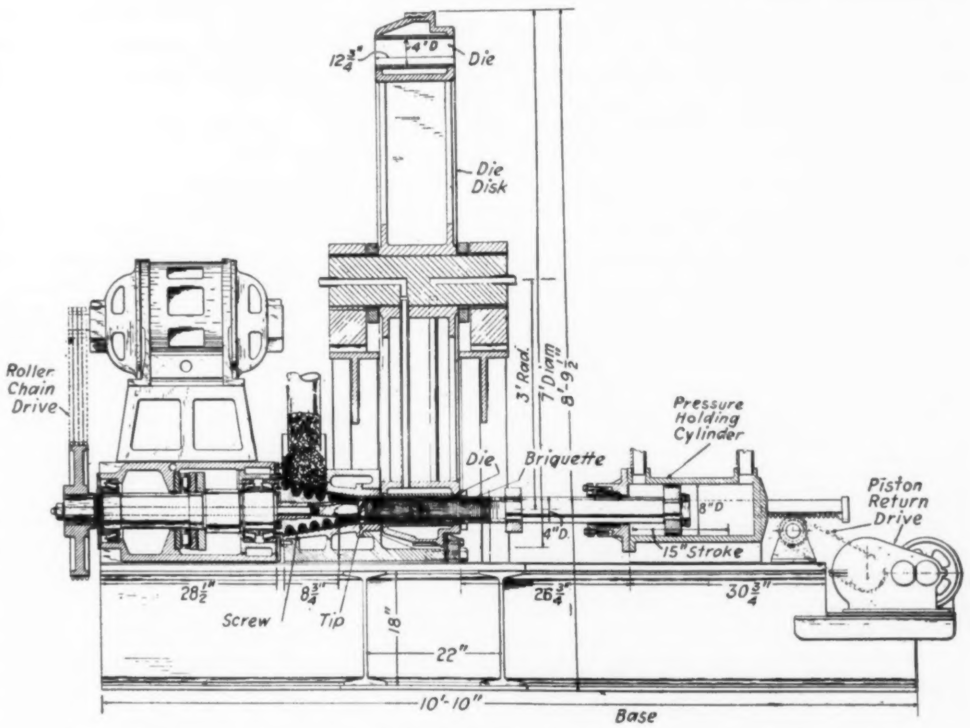


FIG. 2 SECTIONAL DRAWING SHOWING COMPLETE DETAILS OF WOOD-BRIQUETTING MACHINE

the length of screw, amount of taper, pitch of threads, angle of threads, etc., to make the screw feed and press the desired quantity of material to the required density. All the problems involved in obtaining this correct feed did not concern the screw alone, but also the cylinder in which the screw revolved. This cylinder must be ribbed or rifled to prevent the material from turning with the screw. This was accomplished by grooving the walls of the cylinder for the length of the screw. The space ahead of the screw, between the end of the screw and the rear face of the tip forming head, was ribbed by electric-welding Stellite to the surface of the cylinder. This means effectively prevents material from turning with the screw.

This pressing screw is supported on a heavy shaft, the shaft in turn being mounted on two radial bearings. Between these two radial bearings is located a thrust bearing to take the thrust loads of the pressing screw. This thrust bearing was one of the most troublesome parts of the machine. After many bearing failures, a vertical tapered roller thrust bearing solved the bearing problem and is now standard equipment. The pressing screw is removable from its supporting shaft as it must be repaired occasionally because of the abrasive nature of the material being pressed by the screw.

The development of the tip forming head was also a matter of experimentation. The object of this head is to transpose partially compressed material to a second stage of compression without loss of compression or interference with the constant flow of material, and to press the material, during the second stage of compression, to its final density.

The requirement of hardening, or hard-surfacing this tip-forming head to withstand abrasion, was one of the most difficult problems. Many experiments were required to determine the shape of the cams on both sides of the head and the size and shape of the slot through the head, as well as size and length of spindle of the tip head. In the development of this head, practically all known methods of treating steels for hardening were tried. The desired hardness could be obtained, but could not be maintained when placed in operation. Heat developed by friction in pressing the material would soon draw the temper of the steel.

The alternative to heat-treating was the application of some type of hard-surfacing material. Several such materials are available and the method of their application to steel is well known. In the application of these hard-surfacing materials with the acetylene torch, there is danger of overheating or burning the metal to which the hard-surfacing material is being applied. This was overcome, in so far as application to the tip forming head was concerned, by preheating the entire head before the hard-surfacing operation. After the tip head and spindle is hard-surfaced it is ground to size by special grinding equipment developed for this purpose only.

RECENT IMPROVEMENTS IN BRIQUETTING MACHINE

From the time of inception of the tip forming head and up to the early part of 1939, the tip head formed a flat smooth-surfaced layer in the briquetting process. While a briquette made up of these smooth-surfaced layers was extremely dense, it would break in two or more pieces with rough handling and, at times, the layer on the end of the briquettes would break off. To eliminate this fault of the briquettes, an improvement was incorporated in the tip forming head, in the form of three concentric ribs on the front cam face. As previously stated, the front face of the head presses the material into its final density; therefore, any desired change in the shape of the layer would have to be made by a change in this face of the head. The three concentric raised ribs of this face make indentations or corrugations in each layer of material conforming with the shape of the pressing head, thereby interlocking the layers as they are formed. This interlocking of the layers makes a stronger briquette mechanically, and increases production but does not increase the density of the original briquette.

The tip forming head is removable from the pressing screw, since it receives more wear than any other part of the machine. A tip head will ordinarily make 400 to 600 tons of briquettes without repairs. Usually several repairs are made before the tip is useless. It is not unusual for a tip forming head to make a total of 750,000 briquettes.

Further improvement of the tip forming head has been made. It is desirable to increase the production of the briquette machine to the largest possible output in order to make briquettes at the lowest possible cost. The latest development to increase production is the double-headed tip forming head. This head provides means for a three-stage compression instead of two stages as has been described. The theory of the three-stage-compression unit is that more heat and more pressure may be applied to a given quantity of material in the same time. Therefore, more material may be pressed into a briquette in the same time as is now required with a two-stage-compression unit.

The cylinder in which the pressing screw and tip forming head rotate is designated as the screw housing and cone liner. The cone liner is the part in which the pressing screw and tip-forming head actually work. This liner is removable from the housing, as it is one of the parts of the machine which require replacement in relation to the quantity of briquettes produced. This liner is hard-surfaced in the same manner as the pressing screw and tip forming head.

The dies in which briquettes are pressed for cooling are made of 18-8 stainless steel. Experience indicated that these dies must be of a noncorrosive material and one with a low coefficient of friction. The inside dimensions of the dies is controlled by the species of wood material being briquetted. With some species, the bore of the die may be straight. In others the bore may be tapered as much as 0.040 in. in the die length.

The die wheel in which the dies are retained is a steel casting, supported by a central shaft. Space is provided around the dies for the circulation of cooling water. On the outer rim of the die wheel, several notches are cut for indexing the wheel from die to die when briquettes are being made.

The index mechanism is the means provided for turning the die wheel, consisting of a hydraulic cylinder with its piston and rod. The piston rod is attached to the wheel through a set of arms and a ratchet pawl. Pressure for the cylinder is provided by a motor-driven gear oil pump. The pump is operated only when required to index the wheel. The pump develops a maximum of 500 psi with a capacity of 50 gpm. This volume and pressure index the wheel from one die to the next in 4 to 5 sec. A number of mechanical devices were experimented with for this indexing, but none was as effective or as satisfactory as the hydraulic system.

The yielding-pressure-control mechanism, while an important feature of the machine, involved no particular problems of design, as did the pressing screw or tip forming head. This yielding-pressure-control mechanism is nothing more than a hydraulic cylinder with its piston rod attached to a crosshead to which is connected two guide rods for mechanical actuation. Therefore, the rod may be actuated either by hydraulic means or by mechanical means. The hydraulic method is for the purpose of holding a given pressure against a briquette, while it is being formed. The mechanical means is for the purpose of releasing the cooled briquette which has been removed from the die by formation of a new briquette, and to return the piston rod to the starting position.

The controls of the machine are electrical. Two sets of controls are provided; one for automatic operation, the other for

(*Continued on page 124*)

The Tale of

TWO CITY STATIONS

A Half Century of Progress in Steam-Power Generation

By ARTHUR M. GREENE, JR.

DEAN EMERITUS, SCHOOL OF ENGINEERING, PRINCETON UNIVERSITY

DURING my freshman year at Pennsylvania, the *Philadelphia Times*, for March 13, 1890, published a number of articles referring to the largest electric-light plant in the world of that day, the Sansom Street Station of the Edison Electric Light Company of Philadelphia. According to the *Times*, this was rated as an 80,000-lamp station, while the New York system after six years of operation was supplying 36,000 lamps from its three stations, the Boston system 25,000 lamps from two stations, and Chicago had a single station built in 1887. These early stations were rated by the number of 16-cp lamps which they could supply.

The 16-cp carbon lamps consumed 55 w, giving 3.6 lpw. The present 50-w Mazda lamp gives 10.2 lpw, approximately three times as much as the original lamps. The newest fluorescent units of today give from 40 to 60 lpw.

The station delivered its first current at 4:50 p.m., March 5, 1889, supplying current to the Union League on Broad Street and Morgan's Drug Store at 1629 Walnut Street, each about three quarters of a mile from the station.

The station was well known to me as a young engineering student and I believe that the description of it may be of interest in showing the difference between the practice in power generation and utilization of that day and that of a half century later in another station of the Philadelphia Electric Company system. These changes from the earlier practice to that of the present have occurred in the period of my engineering experience.

CONDITIONS RELATING TO EARLY STATION

The territory supplied from the Sansom Street plant covered the mercantile, financial, legal, and business district of Philadelphia, probably an area of three to four square miles, including within its boundaries some of the largest residences. The distribution was arranged on the Edison three-wire system with about 115 volts between the neutral and either leg. The length of trenches for the cables was twelve and one-half miles and in these were 34 miles of ducts with the same mileage of three-conductor cable. The cost of copper amounted to $500,000, about one third of the cost of the complete system and two thirds of the cost of distribution equipment of the ducts, manholes, and cables. It was undoubtedly this copper cost which fixed the location of the station at or near the load center on an expensive site with a poor subsoil and at least one mile from railroads or boats for coal supply or ash removal, and adjacent to mercantile buildings. Moreover, there was no condensing water for efficient steam operation with low back pressure.

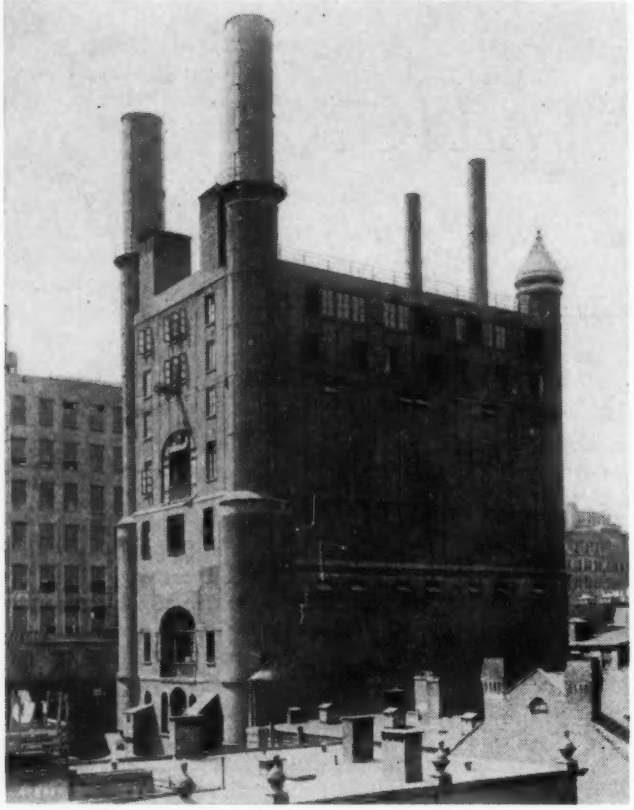
The building was erected on a concrete mat of varying thickness, ten feet at some places and four feet at others. It had a frontage of 70 ft and a depth of 97.5 ft. When completed, the building had eight floors of varying heights. The ground floor was occupied by Armington and Sims high-speed engines, and each of these was belted to a pair of 115-v d-c generators on the second floor, the neutral lead of the three-wire system being connected between them. The third floor was occupied by four forced-draft fans and two smoke breechings receiving the downward discharge of the flue gases from the boilers on the fourth floor. The fifth floor of the finished station was a replica of the third floor with flues and fans for the boilers on the sixth floor. The seventh floor was used for the coalbin and feedwater drums, and the eighth floor just below the roof was used for offices, although as I remember the station, I believe repair shops were also located on this level.

Twenty Armington and Sims engines of 500 ihp were operated with steam at 125 psi gage pressure. Steam was furnished from twenty-eight 500-hp water-tube boilers, arranged in four batteries of seven units, two of them on each boiler-room floor. These were placed against the side walls of the building with the hand-firing aisle between them. Coal was delivered into small cars, which were raised to the seventh floor and run over the coalbin for discharge through spouts, while ashes were collected in cars on the third and fifth floors. The cars were brought to the proper level and the ashes dumped into bins or carts for removal from the station property. The exhaust steam was delivered into the atmosphere although its use for commercial steam heating was thought of originally. The 165-kw generators weighed 18 tons and stood 10 ft high with a breadth of 6 ft.

From my test experience during this period I believe that these engines used at least 40 lb of steam per kwhr and that the boilers attained an efficiency of 60 per cent. If this be the case the station performance was 60,000 Btu per kwhr, an over-all efficiency of a little less than 6 per cent. The reasons for this low efficiency were the small temperature range in the engines, the inefficiency of the boilers, the loss from the belt drives and from the generators, as well as the absence of devices by which a regain of energy was possible from parts of the system wastes.

In the early days, the charge for a 16-cp lamp-hour, or its equivalent, was $1^1/_8$ cents. When this price was compared with the cost of gas, giving the same amount of illumination, it was found that the justifiable gas cost was $2.25 per 1000 cu ft. As gas at that time was sold at $1.50 per 1000 cu ft, the selling price of electric energy was reduced to $^3/_4$ of a cent per 16-cp lamp-hour. This was believed to be lower than the price of current in any other city in the United States or in the world. The early price was the equivalent of 20 cents per kwhr and the reduced price to 13.6 cents per kwhr. Shortly after starting the plant, a minimum charge of $5 per month was fixed for all consumers having twenty 16-cp lamps or less. For

A Sigma Xi Address, Princeton University, Princeton, N. J., May 13, 1940.



GENERAL VIEW, LOOKING NORTHWEST, OF THE EDISON STATION, 9TH AND SANSOM STS.

all lights installed beyond twenty, a minimum charge of 26 cents per month was added per lamp or its equivalent. This covered the yearly cost on the equipment necessary to serve the customer. In this schedule 10 lamps were considered as equivalent to a horsepower.

To meter energy, about one one thousandth of the current was shunted through an electrolytic cell and, once in four weeks, the cells were changed; from the average of the increased weight of one zinc plate of the removed cell and the decrease of weight of the other, the current supplied was computed and expressed in 16-cp lamp-hours; bills were computed with the minimum charge made in months of low consumption.

SANSOM STREET PLANT BECOMES A SUBSTATION

This station continued to be the central station for this district until the alternating-current system, first developed by the Westinghouse Company, was available for transmission from stations at a distance. The company then erected its station A-1 at 28th and Christian Streets on the Schuylkill River in 1903. Here transportation for fuel and refuse, as well as condensing water, was available. Alternating current was generated at higher voltages and transmitted to substations for conversion into direct current for three-wire distribution or stepped down by transformers for alternating-current utilization. The steam turbine was available at this time as a prime mover and vertical turbogenerators were installed. In this new station, the temperature range in the steam cycle was increased by an increase in steam pressure and by the reduction in back pressure through the use of condensers, so that a performance of 34,000 Btu per kwhr was obtained at the station. Sansom Street became one of the numerous substations of the growing system.

The A-2 station at Schuylkill was added to the A-1 station in 1916, and again performance was improved by newer turbine on horizontal shafts to which superheated steam was supplied. In 1917, the company had four generating stations with 200,000-kw installed capacity and 30 substations. This capacity in terms of the early ratings would care for 4,000,000 lamps of 50 w—over 45 times that cared for by Sansom Street.

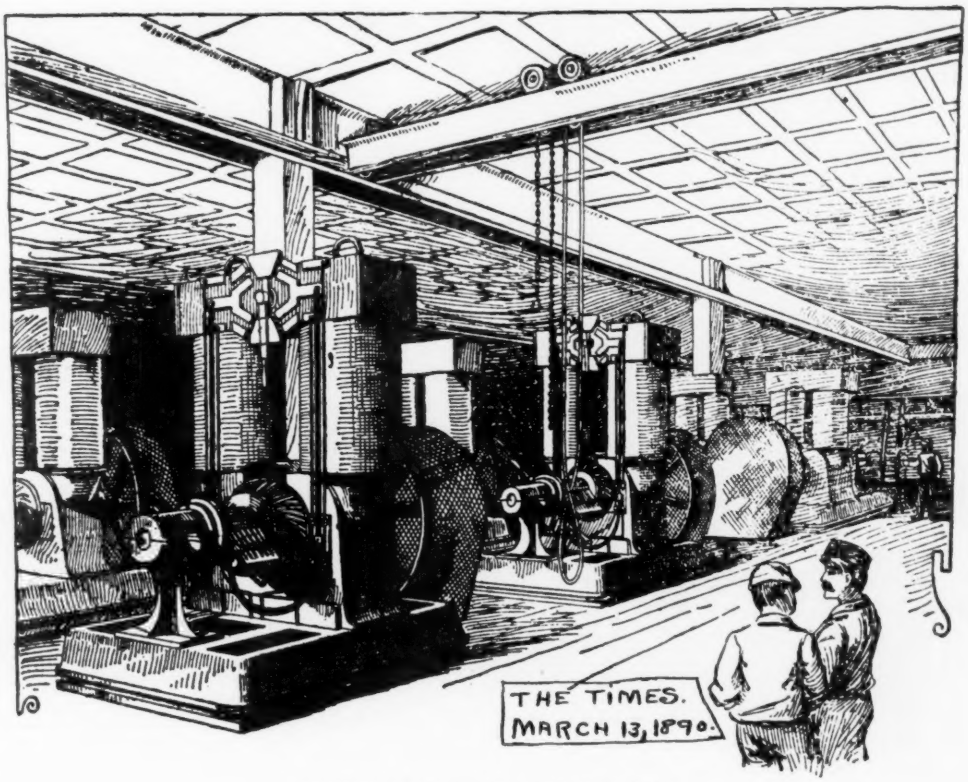
MODERN STATIONS AT PHILADELPHIA AND CHESTER

The Philadelphia Electric Company now added several large modern stations in Chester and in Philadelphia, as well as a hydroelectric station at Conowingo on the Susquehanna. With the newer stations of much greater efficiency than that of the combined A-1-2 stations, these units at Schuylkill were used for stand-by purposes to be employed only when load could not be carried elsewhere. The plant was not abandoned but its average output would equal its capacity generation for less than 10 days per year.

Within recent years the demand for greater capacity in the system has resulted in a study of possible changes in this stand-by station. The later horizontal turbines of this plant had a total capacity of 85,000 kw and were operated at 215 psi gage pressure with 150 F superheat. These turbines utilized most of the river flow for condensing purposes. There were a number of inefficient vertical turbines of the A-1 installation with forty boilers in plant A-1 and twenty in A-2. It was apparent that one method of obtaining more capacity, without increasing the demand for cooling water, would be to install a turbogenerator, operating with high-pressure steam and exhausting at a pressure slightly above that required for the later turbines of the plant, using the exhaust steam for their supply. Such an installation of a high-pressure unit to discharge into existing turbines of a station is known as "topping." In this case, the topping capacity was made 50,000 kw with steam at 1350 psi gage pressure and a temperature of 910 F for the superheated steam. To make this improvement, twenty four of the

CROSS SECTION THROUGH ORIGINAL EDISON STATION, BEFORE ADDING SECOND FLOOR OF BOILERS

old boilers of the A-1 station were replaced by two new boilers, each capable of delivering 600,000 lb of steam per hr, and the turbine was installed in space freed by the removal of an old 15,000-kw vertical unit. Thus, on the same ground space and with the same condensing-water supply, an increase of capacity of 50,000 kw was possible.

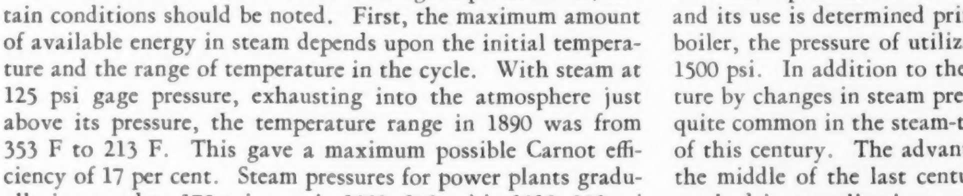


DYNAMO ROOM OF THE EDISON STATION

ANALYSIS OF IMPROVED PERFORMANCE FROM TOPPING

Not only did this topping give additional capacity but the performance of the station was changed from 22,000 Btu per kwhr, the best result with the three later turbines, to 11,800 Btu per kwhr, a value which resulted in the change of the station from a stand-by plant, utilized at $2^1/_2$ per cent of its capacity, to a base-load station, using less than one pound of coal per kilowatthour as compared with the five pounds of coal for such an output in the case of the Sansom Street Station.

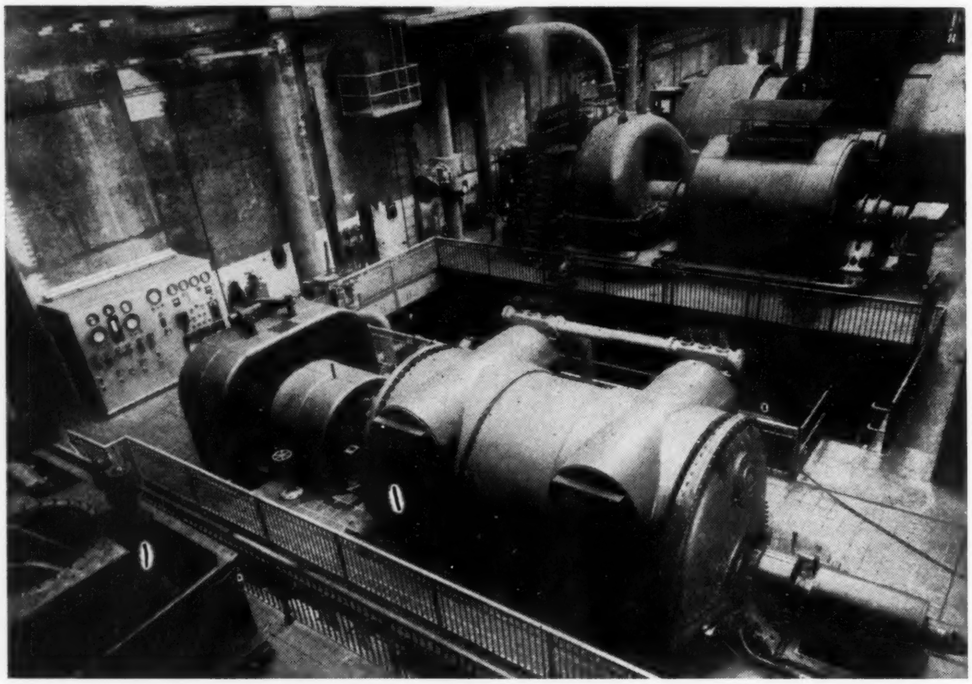
To make clear the reasons for this change in performance, certain conditions should be noted. First, the maximum amount of available energy in steam depends upon the initial temperature and the range of temperature in the cycle. With steam at 125 psi gage pressure, exhausting into the atmosphere just above its pressure, the temperature range in 1890 was from 353 F to 213 F. This gave a maximum possible Carnot efficiency of 17 per cent. Steam pressures for power plants gradually increased to 175 psi gage in 1903, 250 psi in 1910, 350 psi in 1916, 550 psi in 1922, and 1200 psi in 1923. The pressure of 3200 psi was used in England with the Benson boiler in 1923. This latter pressure is that of the critical temperature of water and its use is determined primarily by structural details of the boiler, the pressure of utilization after throttling being about 1500 psi. In addition to the increase in the range of temperature by changes in steam pressure, the use of superheat became quite common in the steam-turbine plants of the second decade of this century. The advantages of superheat were known at the middle of the last century but its application in engines resulted in complications so that it awaited the introduction of the turbine for full utilization. The superheat of 150 F in 1916 gave a temperature of 550 F. This final temperature was gradually increased so that, in 1929, The Detroit Edison Company used 1000 F for one of its turbines. With such high temperatures, the strength of materials is decreased so that special alloys are required for piping, valves, and fittings as well as for parts of the turbine.



ENGINE ROOM OF THE EDISON STATION

The reduction of the back pressure by the use of the steam condenser for the decrease of the low temperature of the cycle has been practiced since the time of James Watt, 170 years ago but, as this required condensing water, it was not used at Sansom Street. In passing, it is well to note that the physical condition for engine operation makes an absolute pressure of 2 psi the

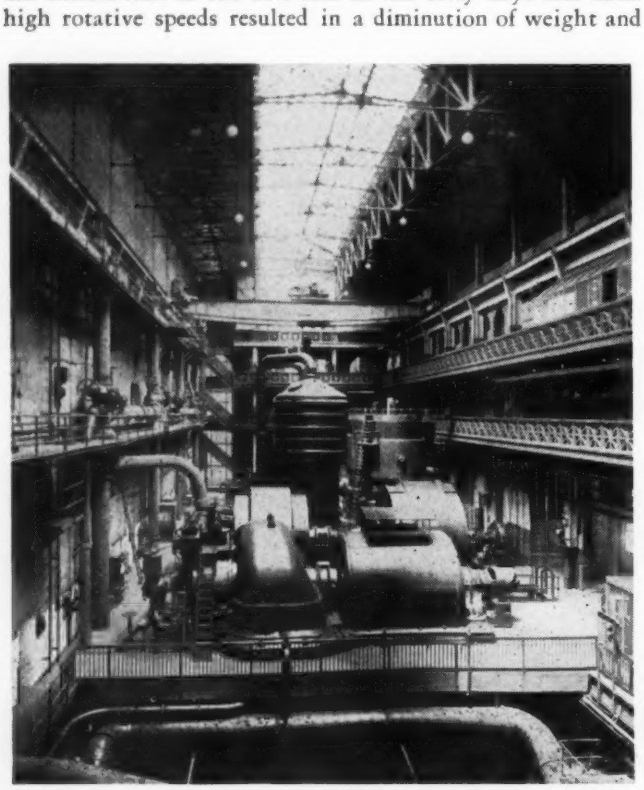
point of maximum return while, with the steam turbine, the lowest possible pressure is efficient because of the physical conditions of its operation. With the conditions of the topped station of 1350-psi steam, superheated to 910 F and with river water at 75 F, the maximum possible efficiency (Carnot efficiency) is 61 per cent, a great increase over that of 17 per cent of the Sansom Street Station.



SCHUYLKILL STATION A-1 TURBINE HALL; 50,000-KW SUPERPOSED UNIT IN FOREGROUND, AND 20,000-KW UNIT AND BAROMETRIC CONDENSER IN BACKGROUND

ADVANCES IN STEAM-POWER GENERATION

The vertical Curtis turbines at Schuylkill, in 1903, were among the earliest used in the United States. The first Parsons turbogenerator was used in the shops of the Westinghouse Company in 1899, and the second was installed by the Hartford Electric Company in 1901. The capacity of the former was 400 kw and that of the latter 1500 kw. The sizes of turbines then increased to 5000 kw in 1903, 35,000 kw in 1914, 90,000 kw in 1926, and 208,000 kw in 1929. These turbines with their direct connections resulted in the elimination of the belt loss of the early days and their high rotative speeds resulted in a diminution of weight and cost. The absence of initial condensation, as in the case of the steam engine, and the ability to use steam effectively down to the lowest possible pressure were responsible for the greater inherent efficiency of these machines.



SCHUYLKILL STATION A-1 TURBINE HALL; 20,000-KW UNIT IN FOREGROUND, VERTICAL TURBOGENERATORS AND BAROMETRIC CONDENSER IN BACKGROUND

The turbine-boiler cycle departs from the teachings of Carnot, regarding the addition of heat at one temperature, in that feedwater is gradually heated from an outside source. In the modern cycle, steam for feedwater heating is bled from the turbine casing at various points after available energy above the pressures of such points has been utilized by the blades. In this way the temperature of the feed is raised to a point approaching that of boiling by heat from within the cycle, confining most of the external heat to use at constant temperature. These regenerative cycles use from two to five stages of bleeding for the feedwater heaters.

To eliminate erosion of the blades, it is desirable that the free moisture, due to abstraction of energy from the steam, should not exceed 12 per cent at any point of its use. To insure this, the initial steam is highly superheated for some turbines and in others the steam is resuperheated after it has expanded to an intermediate pressure and before it is used in the lower stage of the compound unit. Reheat and regeneration are responsible for an appreciable increase in efficiency of modern turbines although, in this topping turbine at Schuylkill, the initial conditions were so chosen that the exhaust without reheat was at 215 psi gage with 150 F superheat, the initial condition for which the station turbines were designed.

In this turbine room, full utilization of waste heat is practiced. Frictional heat is removed from the lubricating oil through interchangers by the feedwater, and the hydrogen used for cooling the generator also serves to warm this feed, Even the exhaust steam from the jet air evacuators of the condensers returns all of its energy to this water.

Hydrogen is used to cool the generators because of its lower density which reduces the windage losses, while its viscosity and coefficient of conduction give lower values of film resistances to heat flow in the interchangers.

The steam-jet air pump not only makes a less-bulky machine

for this service but by its use higher vacuums are possible with the same cooling water. The attempt is made in these modern stations to utilize all of the wastes that were present in the earlier stations.

MODERN EQUIPMENT SIMPLIFIES BOILER OPERATION

The improvements in the boilerhouse of this station are seen in the use of air preheaters, economizers, pulverized fuel, large combustion space, mechanical handling of coal and refuse, soot blowers, evaporators, and continuous blowdowns.

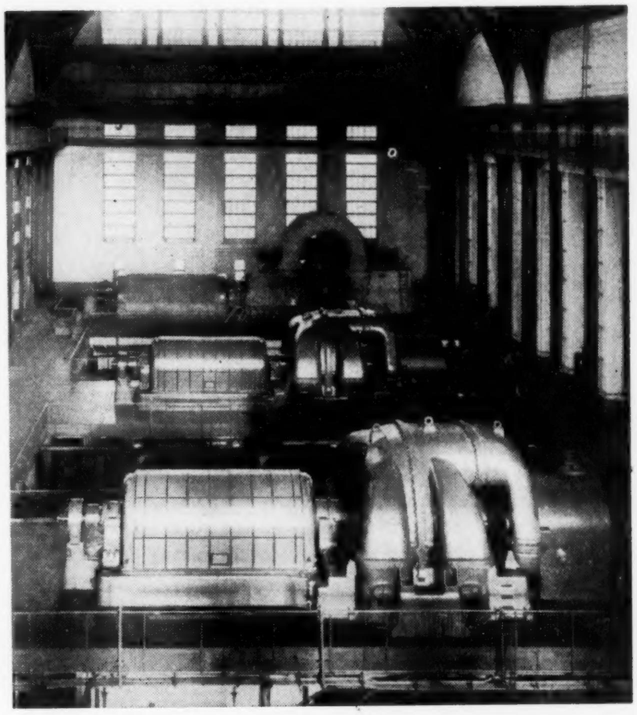
The use of pulverized coal permits a more intimate contact of fuel and air and this with hot-air supply reduces the amount of excess air needed to prevent the formation of carbon monoxide. Hence, the weight of flue gas is decreased. The temperature of these gases is reduced by heating the feedwater in part of the boiler and then by the air preheaters, which deliver air to the furnace at 525 F, with the reduction of the gas temperature to 375 F instead of a possible temperature of 650 F. The furnace has been made of such a volume that 27,300 Btu are released per cu ft per hr, an amount necessary to assure complete combustion before the gases reach the water tubes, when producing 600,000 lb of steam per hr.

To maintain proper heat transfer through the boiler tubes, soot on one side is removed by modern soot blowers, while scale is prevented by using distilled water from evaporators. Ionic concentration control and deaeration prevent corrosion, while electric fly-ash precipitators prevent a nuisance. These, although not affecting heat transfer, reduce maintenance costs and the troubles resulting from outages, as well as public objections to a city plant.

The soot blowers of Sansom Street were pipe lances which were manipulated by hand when under steam. This was such an unpleasant task that seldom was the deposit thoroughly removed. Today, the rise in exhaust-gas temperature to a set limit indicates that the tubes are dirty, and the mere pulling of a chain operates the blowers. The heat of the blowoff from the boilers is utilized in the continuous-blowdown apparatus so that even this small loss is eliminated.

The methods of handling fuel, ash refuse, and water and the control of boiler operation have been so improved that the number of operators of this station of 180,000 kw is not much greater than that of the crews of the Sansom Street station of 6000 kw.

In addition to the improved powerhouse apparatus, mention must be made of the control instruments by which operating conditions may be known at any instant, and data obtained,



RICHMOND STATION TURBINE HALL, SHOWING TWO 60,000-KW UNITS IN FOREGROUND AND ONE 165,000-KW UNIT IN BACKGROUND

from which performance may be definitely computed in physical or monetary values.

From the details given, it is apparent that the careful study of the cycle, as well as the elimination of each small element of waste, have changed the performance of 60,000 Btu per kwhr at Sansom Street to that of 11,800 Btu at Schuylkill, and the sale price to the domestic consumer from 20 cents per kwhr with a $5 minimum charge, to an average of 3.75 cents per kwhr and a minimum charge of 75 cents. The cost of 1 kwhr for the householder has been reduced to less than 20 per cent of the early price, and the common lamp of today gives us light at one third the energy consumption, so that the monetary cost of lighting is one fifteenth that of 1890. This cost will be yet further decreased within a few years because of constant technical developments in this field.

RICHMOND STATION FROM DELAWARE RIVER

CALCULATION CHARTS *for* AIR CONDITIONING

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PROBLEMS encountered in the field of air conditioning show a wide variation in the requirements that must be met. In general, the desired room conditions, the amount of fresh air, and the cooling-coil temperature all vary widely with the requirements of the job. The specific requirements are determined from the purpose for which the air conditioning is to be installed.

Industrial air conditioning is applied to a large variety of manufacturing plants to maintain conditions which afford the most efficient production. These conditions, of course, vary with the material being used and the operations taking place. Yet other conditions are necessary for comfort cooling during the summer months. Since comfort air conditioning is so widely applied, the conditions which are necessary for comfort within a structure have been the subject of careful investigation.

In the air-conditioned research residence, studied by Walker and Helmrich (1),[1] an inside temperature of 79 F was used on the hottest days, while the relative humidity at the end of cooling was of the order of 50 to 55 per cent. McConnell and Kagey (2) investigated the air-conditioning system of an office building and found that the average range of indoor temperatures, maintained for the comfort of the occupants during the summer months, extended between 74 and 79 F, with a range of relative humidity between 43 and 53 per cent. Houghten and Gutberlet (3) and later Houghten, Giesecke, Tasker, and Gutberlet (4) studied cooling requirements for summer-comfort air conditioning and found the upper limit of comfort reactions of subjects to be 80 F, when a relative humidity of 50 per cent was maintained. A study of summer cooling in a research residence was conducted by Kratz, Konzo, Fahnestock, and Broderick (5). They concluded that an indoor temperature of approximately 80 F with a relative humidity below 55 per cent results in satisfactory comfort conditions in the living quarters of a residence. For complete comfort in sleeping quarters, a somewhat lower temperature is desirable. Other investigations have also shown that the standard of comfort can be set at 80 F dry-bulb temperature and 50 per cent relative humidity for summer air conditioning.

The conditions of the outside air, which are identical with the conditions of the fresh-air supply to an air-conditioned structure, vary according to the geographical location (6).

To afford a quick, accurate method of solution for the types of air-conditioning problems discussed, two calculation charts have been designed which are applicable to any problem encountered. The lines drawn on these charts give a permanent record of the problem and its solution and they eliminate the possibility of arithmetical errors. The "Universal Air-Conditioning Calculation Chart" is designed to apply to the general problem of industrial air conditioning where a large range in requirements is found. The "Standard Air-Conditioning Calculation Chart" is for the calculation of problems which require that conditions of human comfort be maintained within the structure.

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

PROBLEM ILLUSTRATING USE OF UNIVERSAL CHART

The use of the Universal calculation chart to air conditioning can probably be shown in connection with the solution of a specific problem. The structure which will be considered has a sensible-heat load of 27,500 Btu per hr and a latent-heat load of 8000 Btu per hr, giving a total internal heat load of 35,500 Btu per hr. This total heat value does not include the fresh-air load of the structure. The fresh-air supply required is, of course, dependent upon a number of factors, such as the number of people present, etc., but for the example, a fresh-air requirement of 210 cfm will be assumed.

The state of the fresh-air supply is taken as 95 F dry-bulb and 78 F wet-bulb temperature. The inside design conditions of the air, insuring comfort in the structure, are 80 F dry-bulb temperature and 50 per cent relative humidity. These conditions are, of course, part of the typical problem under consideration, but actually they may vary according to the requirements of the problem.

The chart consists of six scales on which the exact magni-

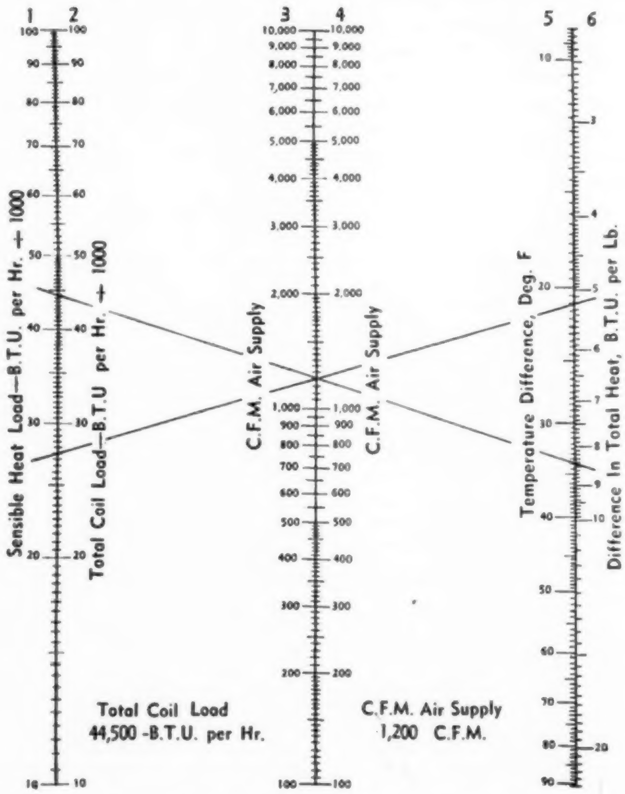

FIG. 1 UNIVERSAL AIR-CONDITIONING CALCULATION CHART

tude of the figures is stated. However, the scales can be used for any multiple of 10 for the figures if the answers are, in turn, corrected for this deviation. The chart is so constructed that all figures on the left of the scales are used in determining the required cubic feet per minute of air supply, while all figures on the right of the scales determine the total coil load in Btu per hour.

To obtain the required air supply in cubic feet per minute from the Universal chart Fig. 1, the sensible-heat load on the structure is located on scale 1 and the temperature difference which the air undergoes, in degrees F, is located on scale 5. This temperature difference is the change in dry-bulb temperature the air undergoes from the time it leaves the cooling coil until it is warmed to room conditions. Its value is given as (80 — 59) or 21 F.

The points of 27,500 Btu per hr sensible heat on scale 1 and 21 F on scale 5 determine a straight line which intersects scale 3 at a required air supply of 1200 cfm.

It remains to find the total load on the coil in Btu per hour. Since scales 3 and 4 are identical, the same value of cubic feet per minute may serve for both. The difference in total heat content in Btu per pound of dry air, as it is conditioned, is located on scale 6. This difference is equivalent to the quantity of heat removed by the coil per pound of dry air and amounts to 8.4 Btu per lb of dry air for the example.

By locating 8.4 Btu per lb on scale 5 and 1200 cfm on scale 4, a straight line may be drawn and extended until it intersects scale 2. At this intersection, the total coil load is found to be 44,500 Btu per hr. The total coil load includes both the sensible- and latent-heat loads of the room, together with the heat load of the fresh-air supply.

ASSUMED CONDITIONS ON WHICH THE STANDARD CHART IS BASED

From a consideration of the investigations of personal-comfort conditions, the standard inside design conditions will be set at 80 F dry-bulb temperature and 50 per cent relative humidity. The design dry-bulb temperature of the outside fresh air will be set at 95 F and the wet-bulb temperature of the fresh air (outside conditions) will be allowed to vary from 70 to 80 F, depending upon the geographical location of the structure.

Based on the specifications given for the standard air-conditioning job, the Standard air-conditioning calculation chart, Fig. 2, has been designed. This chart differs from the Universal chart in that it is only necessary to know the internal sensible- and latent-heat loads, the amount of fresh-air supply (and the conditions of this air supply), in order to obtain a solution from the chart. Using the Universal chart, it was necessary to know, in addition to the foregoing data, the conditions of the air entering and leaving the cooling coil. These values may be determined from a psychrometric chart or by outright assumption.

THE STANDARD-CHART SOLUTION

The application of the Standard air-conditioning calculation chart, Fig. 2 may also be illustrated by the solution of a definite problem of the type referred to. Since the problem, which has been outlined in connection with the Universal chart, falls into this category, its solution on the Standard chart will illustrate the use of the chart and, also, the results obtained may be compared with those previously obtained from the Universal chart. The Standard calculation chart, as will presently be shown, is so constructed that, by drawing three lines through the chart, the values desired for a solution of the problem may be read quickly and directly.

The term per cent sensible heat, used in the calculation chart represents the relationship between the sensible-heat

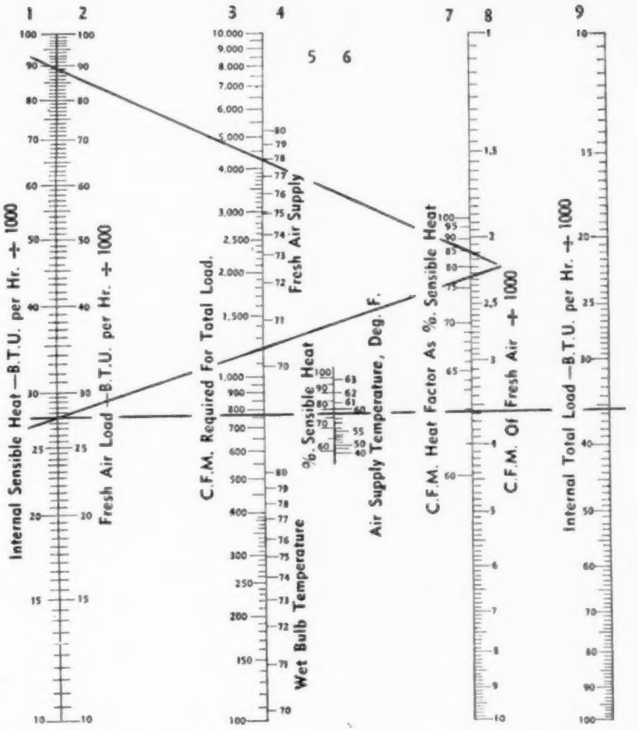

FIG. 2 STANDARD AIR-CONDITIONING CALCULATION CHART

(Scale 5, per cent sensible heat, 77.5; scale 6, air-supply temperature, 59 F; scale 3, air required, 1200 cfm; scale 2, fresh-air load, 8900 Btu per hr; internal total load, 35,500 Btu per hr; total coil load, 44,400 Btu per hr.)

load and the total heat load. For the example stated, with a total heat load of 35,500 Btu per hr, the per cent sensible heat becomes

$$\frac{27{,}500 \times 100}{35{,}500} = 77.5 \text{ per cent}$$

Only those problems in which the per cent sensible heat lies between 60 and 100 per cent can be solved on the Standard chart. If the per cent sensible heat lies below 60 per cent, the problem must be solved directly from a psychrometric chart. In most of these cases, the conditioned-air supply must be reheated as it leaves the cooling coils, so that it can be obtained at the required conditions.

In the solution of any problem, the per cent sensible heat must first be obtained. This is done by locating the sensible-heat load on scale 1 and the total heat load on scale 9. For both of these scales, the word "internal" is used in the label, which merely signifies that these loads are loads on the structure alone and do not include the fresh-air load. When these two points are determined, they are connected with a straight line and the per cent sensible heat is read at the intersection of this line with scale 5.

The nine scales of the calculation chart Fig. 2 are all labeled and the magnitude of the figures is indicated. However, since the scales are in logarithmic form, the magnitude of the figures can be varied by multiples of 10. When this is found necessary, close check must be kept on the decimal points of the answers obtained, since they are directly affected. For the values indicated on the scales, all results are indicated in the correct magnitude.

Returning to the example, the sensible-heat load of 27,500 Btu per hr is located on scale 1; and the total heat load of 35,500 Btu per hr is located on scale 9. The line connecting these two points is found to intersect scale 5 at a per cent sensible heat

of 77.5 which exactly corresponds to the previous calculation.

This same intersection is used to determine the temperature of the air supply as read on scale 6. This is the dry-bulb temperature at which the air must leave the coil, assuming a relative humidity of 90 per cent, so that the proper inside conditions of the structure may be maintained. The temperature obtained from the calculation chart is 59 F, which is the value found previously by referring the problem to a psychrometric chart.

It is now possible to determine from the calculation chart the quantity of air required to handle the load on the structure. To accomplish this, the per cent sensible heat obtained from scale 5 is transferred directly to scale 7. With the sensible-heat load previously located on scale 1, the points on scales 1 and 7 may be connected with a straight line. The intersection of this line with scale 3 gives the quantity of air in cubic feet per minute required for the total load. Here, again, the figures do not necessarily represent the exact answer and the decimal point should be checked. If the sensible-heat load is in 5 figures, then scale 3 gives exact answers.

In the example cited, the per cent sensible heat is 77.5 per cent and the sensible-heat load is 27,500 Btu per hr. The quantity of air required, as read from scale 3, is 1200 cfm, which agrees with the previous solution.

It remains to determine the increased load on the coil, due to the fresh-air requirements. It has been previously stated that the total load on the cooling coil is the sum of the "internal" total load on the structure and the fresh-air load. The latter load can be represented as the heat which must be removed from the fresh air in order to change its state to that of the recirculated air. It is not necessary to make this division in a solution on the Universal chart, since the state of the mixtures of fresh and recirculated air must be given.

FRESH-AIR LOAD

Of the 1200 cfm, required in the example, 210 cfm must be fresh air. To determine the fresh-air load, the point representing the cubic feet per minute of fresh air is located on scale 8 and the point corresponding to the wet-bulb temperature of the fresh-air supply is located on scale 4. These two points are connected with a straight line, which is further extended until it intersects scale 2. At this intersection, the load of the fresh-air supply can be determined. This load is then added to the internal total load of the structure and the total coil load is obtained.

The fresh-air load for the example is found by locating 210 cfm of fresh air on scale 8 and the 78 F wet-bulb temperature of the fresh-air supply on scale 4. The intersection of the line connecting these two values with scale 2, shows a fresh-air load of 8900 Btu per hr. The value of cubic feet per minute actually located on scale 8 is 2100 cfm, instead of 210 cfm and, therefore, the fresh-air load must be correspondingly corrected.

The total coil load now becomes the sum of 35,500 Btu per hr "internal" total load and 8900 Btu per hr fresh-air load, giving a total of 44,400 Btu per hr. This corresponds to the value of 44,500 Btu per hr, obtained in the previous chart solution. The tons of refrigeration, required in the calculation-chart solution, become $44{,}400 \div 12{,}000 = 3.7$ tons. Thus, the air-conditioning unit must furnish 1200 cfm of conditioned air at 59 F dry-bulb temperature and 90 per cent relative humidity.

A comparison of the results obtained from the Standard air-conditioning calculation chart and those obtained from a mathematical analysis reveal that the accuracy of the calculation chart is well within the accuracy of the air-conditioning equipment available.

CONCLUSION

Calculation charts have been developed which are capable of solving air-conditioning problems directly and which eliminate much of the arithmetical work.

A Universal Calculation Chart is described which gives the cubic feet per minute and total coil load for a wide range of variations in air conditions.

A Standard Air-Conditioning Calculation Chart is described. This chart has been developed on the basis of standard inside conditions of personal comfort of 80 F dry-bulb temperature and 50 per cent relative humidity, as described in the literature. An outside dry-bulb temperature of 95 F is used, and the chart is applicable for localities where the wet-bulb temperature lies between 70 and 80 F. In addition to the coil load and the cubic feet per minute required, the entering temperature of the conditioned-air supply is found on the chart.

The two calculation charts present a rapid, accurate method of solution of most air-conditioning problems and they should aid in standardizing and simplifying calculations of this type.

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Developments in Meteorology

(*Continued from page 104*)

direction of Dr. J. Bjerknes, and one at the University of Chicago under Dr. Byers. The stimulating effect of these new centers of meteorological investigation on progress in the science will undoubtedly be very great.

Air-line meteorology has developed chiefly in the direction of greater detail and exactness. Much attention is being given to eliminating as far as possible the factor of pure judgment, or experience, and substituting forecasting techniques that make as complete a use as possible of all available data. Ambiguity and inexactness in forecasts have been studied extensively with the result that new types of forecasts are now being used by several major air lines in which these faults are largely eliminated. Increased stress is coming to be laid on the importance of meticulous analysis of synoptic weather charts as a means to accurate forecasts, rather than a close following of apparent current weather trends as shown by hourly weather reports.

All services engaged in forecasting activity are making greater and greater use of aerological data as the network of regular radio meteorograph soundings becomes denser. Much of the current effort in improving the technique of preparing forecasts is devoted to devising new charts to display more clearly and more readily the vast amount of information concerning the upper air now available daily in the United States.

In summary it may be said that during the last twelve months meteorology has progressed greatly, particularly in its essentially practical applications. With the attention now being paid to educational activities in this country, probably this progress will be accelerated still more in the next few years.

Principles of JIG *and* FIXTURE PRACTICE

By JOSEPH W. ROE

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THE combination of a machine tool and the jig or fixture which forms its work-holding equipment must do two things. It must drive a cutting tool of proper form and material in a motion which is exact as to path and often as to distance traveled. It must also hold the work in exact relation to the cutter. Precision in setting and holding the work is as important as precision and power in cutting. No amount of excellence in the machine is of use if the work-holding device is weak or inaccurate.

In hand-tool production, where the operator directs and controls a free cutting tool, work holders are simple in character and of minor importance. Their only function is to hold the piece during some hand operation, a function easily met, as the cuts are light. In machine production the cuts are usually heavy, the thrusts severe, and as the machine is controlling the cutting tool there must be exact register between the work and the cutting tools.

The terms jig and fixture are often used interchangeably. In so far as they are differentiated a fixture is a work-holding device, usually secured to the table of a machine, while a jig is usually free to center itself on the cutting tool. A fixture relies on the machine tool for accuracy of registry between the path of the cutter and the position of the work. In a jig the registry is largely self-contained. The term jig is most commonly used in connection with work-holding devices for drilling operations, although it, as well as fixtures, is also used in connection with devices for babbitting, polishing, assembling, and welding.

Jigs and fixtures have been developed empirically and there is much less technical literature covering them than there is on power machinery and its utilization, or even on the very machines on which fixtures are used. Judging only from the literature available, one would gain no idea of their economic importance. However, the competitive technical advantage of one manufacturing plant over another will usually lie more in the better quality of its small tools, jigs, and fixtures than in differences between the types of machine tools in the respective plants.

The principles of good work-holder practice have grown up in the toolrooms and been handed down from man to man. Due to the multiplicity and variety of articles manufactured, there is a great diversity of fixtures and holding devices, so great as to preclude treatment of all their details in a paper such as this. But through all fixtures there run certain principles which have been developed gradually and come to be recognized as good practice. Many of these principles can be brought together, and it is the purpose of this paper to do this.

The paper also aims to bring out not only the principles of design, but to cover some of the intangible elements and economic principles involved.

ECONOMIC PRINCIPLES

The first and most important element, which applies to all forms of work holders, is the economic one. A certain amount of "tooling up" is an advantage wherever parts are to be produced in quantity, but how far it should go and how much capital should be tied up in special fixtures and tools depends on immediate conditions. The question of the amount of expense justified has been handled largely on the basis of judgment. The besetting sin of the toolmaker is to tie up money in fixtures which may show a heavy saving when in use, but are seldom used. A saving of 5 per cent in labor cost on a job in constant use might justify greater expense in fixtures than a saving of 90 per cent on a small job coming through only once or twice a year. Other factors besides saving in time and labor expense are involved, such as the life of the fixtures, due not only to their own wear, but to possible obsolescence of the article they make. Fixtures *may* be desirable even where only small quantities are involved, but the economic advantage of lower labor costs is the controlling factor unless some other consideration, such as improved interchangeability, increased accuracy, or reduction of labor trouble intervenes. Usually, where these latter reasons alone would have necessitated a fixture, it is found that the fixture lowers costs.

In the books available on work-holding devices are to be found methods of construction, much on the details and examples of good practice in design, but almost nothing on the economics of the subject. Because of this lack, this aspect will be stressed here. It should be the first consideration and is usually given little thought. Few plants give to their fixtures the searching economic analysis which they apply to their power equipment. Until recently, the same has been true for materials-handling equipment; but thanks to the Materials Handling Division of the Society, formulas are now available, and are being increasingly used, which provide a standard basis for the economic analysis of equipment in that field and for determining the probable profit on any proposed installation for given costs and performance. These formulas take into account interest, depreciation, obsolescence, and other items of overhead which theretofore had been either neglected entirely, or had been handled differently by everyone concerned. They can be used, with modifications and simplifications, for tool equipment just as well as for materials-handling equipment, and should be.

The following is a suggested adaptation of them for this use. Certain factors in the materials-handling formulas which are important in installations in that field are of less importance in dealing with fixtures, or may drop out entirely. Others, such as the interest rate, taxes, etc., may be taken as constant and brought together. This permits simplification.

With fixtures, as with other types of equipment, depreciation is made up of two factors, deterioration and obsolescence. As a rule these do not bear equally. In one case deterioration due

Recent intensification of mass production in the cause of national defense has demonstrated the need for engineers well grounded in the principles of jig and fixture practice. At a meeting of the Bridgeport Section of The American Society of Mechanical Engineers held in November, 1940, Jos. W. Roe addressed a large and enthusiastic audience on this subject, basing his address on his paper "Principles of Jig and Fixture Practice," presented to the Society in 1928, for which the Melville Medal was awarded in 1929. The paper has been revised and is republished in order to make it widely available.—EDITOR.

to wear may be the chief factor. More often obsolescence due to liability of change in models or design may control. That one should be used which operates the faster.

In dealing with fixtures, the economic problem centers on answering one or more of the following questions:

1 How many pieces must be run to pay for a fixture of given estimated cost which will show a given estimated saving in direct labor cost per piece? For instance, how low a run must we have to justify a fixture costing $400 which will save 3 cents on the direct labor cost of each piece?

2 How much may a fixture cost which will show a given estimated unit saving in direct labor cost on a given number of pieces? For instance, how much can we put into a fixture to "break even" on a run of 10,000 pieces, if the fixture can save 3 cents on the direct labor cost of each piece?

3 How long will it take a proposed fixture, under given conditions, to pay for itself, carrying its fixed charges while so doing? For instance, how long will it take a fixture costing $400 to pay for itself if it saves 3 cents on the direct labor cost per unit, production being at a given rate?

Questions 1, 2, and 3 assume that we just break even. There is also the very practical question:

4 What will be the profit earned by a fixture, of a given cost, for an estimated unit saving in direct labor cost and given output? For instance, what will be the profit on a $200 fixture if it will save in direct labor cost 3 cents a piece on 10,900 pieces?

These questions involve something more than the simple arithmetic which seems all that is necessary for answering them, because, while the credit items for the fixtures depend mainly on the number of pieces machined, the debit items involve time, and also the number of setups required, i.e., whether the pieces are run off continuously or in a number of runs.

An important time element is that many companies now require that any new equipment shall pay for itself in a certain period. Various investigations show wide variation in practice as to this requirement, ranging from one to six or seven years, the longer period being used by railroad shops which have a stable class of work not liable to rapid obsolescence. The general practice seems to be about two years, but conditions even within one shop might warrant lengthening or shortening this period for different specific cases.

PROPOSED EQUIPMENT FORMULAS

The formulas reduce to the simple and workable forms found in Equations [6], [7], [8], and [9] which follow, but to use them correctly it is necessary to have clearly in mind the meaning of the symbols used.

Let N = number of pieces *manufactured per year*

Debit Factors

A = yearly percentage allowance for interest on the initial investment

(If the interest be taken on the *depreciating* value, this becomes, under uniform depreciation for n years, $A \times \frac{1}{2}\frac{n+1}{n}$, the value of which decreases from A, for one year, and approaches $A/2$ as n grows large. For a life of two years this is $3A/4$, for three years it is $2A/3$. In the following formula either the original cost or the depreciating value can be used with equal facility. It is recommended, however, that one or the other basis be used uniformly to facilitate comparisons.)

B = yearly percentage allowance for insurance, taxes, etc.

C = yearly percentage allowance for upkeep

$1/H$ = yearly percentage allowance for depreciation and obsolescence on the basis of uniform depreciation where H is the number of years required for amortization of investment out of earnings

E = yearly cost of power, supplies, etc., consumed, in dollars. (When the equipment under consideration is wholly new, this item appears in full. When it replaces old methods or equipment, the difference only is used. It is a debit if the E on the new equipment exceeds that on the old. It is a credit if the new E is less than the old. E in the formula may therefore be + or —.) In many cases, with fixtures this item is small and may be disregarded.

I = estimated cost of the equipment or fixture, i.e., cost installed and ready to run, including drafting and toolroom time, material and toolroom overhead, in dollars

K = unamortized value of the equipment displaced, less scrap value, in dollars. (Note: In the case of fixtures for new work, K drops out.)

Y = yearly cost of setups, in dollars. This should include the time required for taking down the apparatus and putting machine into normal condition. In some plants with departments large enough to employ several toolsetters regularly this time can be included in the department overhead. In this case this factor disappears as a separate item

Credit Factors

S = yearly saving in direct cost of labor, in dollars
= $N \times$ (old unit labor cost, minus the new unit labor cost)
= $N \times$ (saving in unit labor cost)
= Ns. This covers *direct* unit labor cost only

s = saving in unit labor cost

T = yearly saving in labor burden, in dollars
= St, where t is the percentage used on the labor saved,
= Nst
(Note: The latest form of the materials-handling formulas breaks this into T_a = burden on labor saved and T_b = burden on the equipment displaced. For use with fixtures the latter element may usually be disregarded for simplification.)

U = yearly saving or earning through increased production in dollars
= saving in unit labor cost $\times$ increased *yearly* production capacity
$\times$ the percentage of that increased capacity which will be utilized
$\times (1 + t)$ (this cares for the burden saved)
+ cost of extra old equipment which would be necessary to care for the increase if the improvement were not adopted
(Note: In many cases U may drop out.)

V = yearly net operating profit, in excess of fixed charges, in dollars.

PROPOSED FORMULAS

If we just "break even" we have:
The yearly operating savings = total fixed charges per year
Using the foregoing symbols

$$(S + T + U - E) - (\text{Yearly cost of setups}) = I(A + B + C + 1/H) + KA$$

$$\text{Since } S + T = Ns + Nst = Ns(1 + t)$$

Then

$$Ns(1 + t) + U - E - Y = I(A + B + C + 1/H) + KA \quad [1]$$

To find the number of pieces required for a given cost I we have, solving for N

$$N = \frac{I(A+B+C+1/H)+Y-U+E+KA}{s(1+t)} \ldots [2]$$

To find the cost I which will just earn fixed charges we have, solving Equation [1] for I

$$I = \frac{Ns(1+t)-Y+U-E-KA}{A+B+C+1/H} \ldots\ldots [3]$$

To find the net operating profit over all fixed charges we have

V = gross operating profit, less setups and fixed charges

$$= Ns(1+t) - Y - I(A+B+C+1/H) + U - E - KA \ldots\ldots [4]$$

To find the time H in years for the fixture to just pay for itself, the net profit V in Equation [4] = 0

Therefore, setting the right-hand side of Equation [4] equal to 0 and solving for H, we have

$$H = \frac{I}{Ns(1+t)-Y-I(A+B+C)+U-E-KA} \ldots [5]$$

In most cases it will be found that U, E, and KA may be neglected, so that Equations [2], [3], [4], and [5] may be written as follows

$$N = \frac{I(A+B+C+1/H)+Y}{s(1+t)} \ldots\ldots [6]$$

$$I = \frac{Ns(1+t)-Y}{A+B+C+1/H} \ldots\ldots [7]$$

$$V = Ns(1+t)-Y-I(A+B+C+1/H) \ldots\ldots [8]$$

$$H = \frac{I}{Ns(1+t)-Y-I(A+B+C)} \ldots\ldots [9]$$

To be of practical value the formulas should be as simple as possible and yet reflect the essential conditions, and should be easily applied.

Equations [6], [7], [8], and [9] meet this condition for most fixtures. They take into account the number of pieces manufactured, the saving in unit labor cost, the overhead on the labor saved, the cost and frequency of setups, interest on investment, taxes, insurance, upkeep, and depreciation. The fuller formulas, Equations [2], [3], [4], and [5], take into account, in addition to the foregoing, the value of increased production capacity, cost of supplies and extra power, and interest on equipment displaced, if it is deemed that conditions require their consideration. These may be used for the more elaborate fixtures and for analyzing the purchase or building of machine tools.

In using the formulas it must be remembered that N is the number of pieces manufactured in a *year*, not per run, except for the case of a single run of less than one year's duration.

The items A, B, and C, once settled upon, need change little. If the plant has the practice of requiring new equipment to pay for itself in a definite time H, say two years, the depreciation $1/H$ may be added to the other carrying charges, making a single percentage factor for the term $(A + B + C + 1/H)$ which can be used until the management deems that changed conditions require modification.

EXAMPLES

To illustrate economic analysis of a fixture by the use of these ormulas, assume the following data:

Estimated unit saving in direct labor cost	= 3 cents
Burden on labor saved	= 50 per cent
Estimated cost of each setup	= \$10
A	= 6 per cent
B	= 4 per cent
C	= 10 per cent
H	= 2 years
$1/H$	= 50 per cent
$A+B+C+1/H$	= 70 per cent

If I = \$400, to find the number of pieces to be put through each year in one run per year, we have from Equation [6]

$$N = \frac{\$400 \times 0.70 + \$10}{\$0.03 \times 1.5} = 6450 \text{ pieces}$$

That is, if a \$400 fixture is to pay for itself in 2 years and carry overhead, with a single run per year 6450 pieces must be put through each year.

If, instead, the pieces are put through in 6 runs per year, then

$$N = \frac{\$400 \times 0.70 + \$60}{\$0.045} = 7550 \text{ pieces}$$

That is, more pieces must be run per year, due obviously to the increased number of setups.

There is of course a breaking point where it pays to have multiple runs, even at a higher production cost per piece, due to the balancing of production costs and fixed charges on increased inventory. Formulas are available elsewhere for determining this economic length of run.

Suppose the fixture is to pay for itself in a single run, how large must that run be?

In this case H is unity, as the fixture must pay for itself within the year, and $A + B + C + 1/H = 6\% + 4\% + 10\% + 100\% = 120\%$ then

$$N = \frac{\$400 \times 1.20 + \$10}{\$0.045} = 10{,}900 \text{ pieces}$$

This says that a smaller *total* output is required than when 6450 pieces are called for, for *two* years, or 12,900, due to one less setup and carrying the overhead for only one year instead of two.

It will be noted that this assumes the full-year values for A, B, and C. If the run is short and it is felt that this is too drastic, the values could be cut down in the proportion of the actual running time to one year. It would be safer and therefore good practice to use the yearly rates, as the time for the complete turnover of the money going into the fixture is hard to determine and certainly is longer than the mere run itself. The cost of short-lived equipment should be extinguished as soon as possible.

Reversing the foregoing assumptions, how much money could we put into a fixture for a single run of 10,900 pieces at an estimated saving of 3 cents per piece? From Equation [7]

$$I = \frac{10{,}900 \times \$0.045 - \$10}{1.20} = \$400$$

Similarly, if we want 7550 pieces a year in six runs per year, and want the fixture to pay for itself in two years, we have from Equation [7]

$$I = \frac{7550 \times \$0.045 - \$60}{0.70} = \$400 \ldots\ldots [10]$$

If we want to know the reverse of this, namely, how long a time it would take a \$400 fixture to pay for itself, we have from Equation [9]

$$H = \frac{\$400}{7550 \times \$0.045 - \$60 - \$400 \times 0.20} = 2 \text{ years}$$

From Equation [10] we see that we would "break even" with a cost of $400. Suppose now we can design a fixture for the same conditions which would cost $250 instead of $400 what will be the *profit?* Using Equation [8] we have, for 7550 pieces per year in six runs per year

$V = 7550 \times \$0.045 - \$60 - \$250 \times 0.70 = \$105$ per year

For a *single* run of 10,900 pieces the profit would be

$V = 10{,}900 \times \$0.045 - \$10 - \$250 \times 1.20 = \$180.50$

Formulas [3] and [7] may be used to help in deciding between two fixtures of different degrees of refinement for the same job. For instance, for a single run of 2000 pieces, under the foregoing conditions, how much can we afford to put

(*a*) Into a fixture if it will save 3 cents per unit, with a setup cost of $10 or

(*b*) Into a more refined fixture which will save 5 cents per unit, with a setup cost of $15

We have from Equation [7]

$$\text{For } (a)\ I_a = \frac{2000 \times \$0.03 \times 1.5 - \$10}{1.20} = \$66.66$$

$$\text{For } (b)\ I_b = \frac{2000 \times \$0.05 \times 1.5 - \$15}{1.20} = \$112.50$$

Obviously also the same formula may be used to compare the amounts which might be put into fixtures for different lengths of run.

The above examples show how the formulas proposed may help in deciding tooling-up problems as they arise. They apply not only to jigs and fixtures but to punches and dies, special tool equipment and, in the fuller forms, to proposed machine tools.

It is recommended that in authorizing expenditures for all fixtures and tools, above some minimum cost which could be set, an estimate be made of the

(*a*) Cost of the fixture
(*b*) Output of the fixture
(*c*) Profit or saving from it.

Also, that when it is put into operation the results be checked with these estimates.

Such a procedure would give a check on the quality of the tool designing. If tool costs are overrunning the estimates and the output and savings falling short, the facts will be shown up. If the tool work is good the management will know it, and have means for measuring the profit therefrom.

CERTAIN GENERAL PRINCIPLES

Before a set of fixtures can be designed the dimensions of the article to be manufactured must be definitely determined. This means that clearances and allowances must be made on certain dimensions for running, sliding, or driving fits. Furthermore the tolerances, or permissible deviations, must be established. These tolerances set the high and low limits for each dimension, which cannot be exceeded without encroaching on the allowances necessary for proper functioning or destroying the interchangeability of the parts. In general the smaller the tolerances the greater the cost of production, consequently they should be as liberal as is consistent with the requirements of the product, and accuracy should be centered on those dimensions on which it is essential. The closeness of the tolerances governs the design and workmanship of the jig or fixture quite as much as the required rate of production.

When the drawings of the article to be manufactured have been checked and approved, a model should be made to within the tolerances given on the drawings. When this has been tested and pronounced satisfactory, any changes found necessary in allowances, tolerances, etc., should be incorporated into the drawings. The model and drawings can then be used as the basis for design of the jigs and fixtures. If during the building of the tools any discrepancy should develop between the model and the drawings, the approved working model should govern, and the drawings corrected to agree with it. When actual model parts are not available, wooden models of such parts as drop forgings, with the location of the sprue and flash line painted on them, may be helpful.

In tooling up for the manufacture of a piece, an operation sheet should be prepared which includes every operation on the piece, both of production and of inspection or gaging, showing them *in a single list* in the order of their application. The preparation of such a list focuses attention not only on the best sequence of production operations, but on the number of inspections needed, the dimensions they should cover, and the best points in the sequence at which they should occur. It also brings out the best grouping of operations and their reduction to the least possible number.[1]

The fixtures should be tied in with the system of gaging. The same points or surfaces should be used for locating the work in the fixtures and for reference points in the gages. Only by so doing are the gages a direct check on the fixtures. Some deviation is made, however, as when inspection gages are made to cover a subassembly of parts in order to insure that certain collective deviations do not exceed permissible tolerances. In some cases, also, as with pistons, it may be desirable to provide lugs especially for holding and driving during manufacture, which are removed in the last operation.

The same working points should be used on the two parts which go together in the manufactured output. This better insures interchangeability of the finished product.

In selecting the working points the functioning of the product and those dimensions which are most important to its operation should be given most careful thought.

It is of fundamental importance that, once settled upon, the same working or locating points be used for as many operations and gagings as possible. Preferably they should be permanent and remain in the piece when finished. If this cannot be done they should be retained as long as may be. If first one point and then another be used, an accumulation of errors creeps in which may exceed the tolerances. It is tempting at times to shift the locating point, as the fixture and gage might then be made more cheaply, but to do so is poor practice, and in the long run, poor economy. As an example of the foregoing, in a set of fixtures recently built for a military rifle, 62 out of 67 operations on one piece, with their gagings, were located from one point.

It *may* be wise to shift the reference point, but it should be done only for good and sufficient reasons. For instance, the position of two holes *A* may be referred to a main reference point. The important requirement of a second hole *B* may be exact distance from holes *A* without regard to the original reference point. In such case both the fixture and the gage would very properly locate *B* with reference to the holes *A*.

If a multiple fixture is to be used, of either the reciprocating or

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[1] An authority consulted contributes the following as the procedure used by one large manufacturer having agencies throughout the world: "When a new machine has been developed to a stage where it functions satisfactorily the agencies are informed, and inquiries are instituted to determine the probable sales for the machine. During this inquiry period the machine is going through a process of refinement. Drop forgings, stampings, grades of metal, hardness, and finishes are being determined. When the approximate yearly sales have been determined manufacture starts by ordering all drop forgings, blanking and bending dies, as these take the longest time to construct. Parts which are odd in shape or difficult to hold are assigned for tooling up, starting in the usual manner, with operation sheets which are provisional, as it is often necessary to revise the sequence of operations. Quality and interchangeability are the main requirements. While quantity will influence the type of fixtures it is possible to make cheaper tools at first with provision for the future if unexpected sales should develop."

indexing type, the question of the time required for removing and inserting pieces is of fundamental importance, as the clamping means must be so designed that the pieces can be handled in the time taken for the cut.

In general it is desirable to machine as many surfaces, or drill as many holes, as possible at one setting. This makes for accuracy, lessens tool expense, and cheapens production, but is subject to some limitations as, for instance, the combination of a very large and very small hole in the same jig. It may be better to use two jigs on different-sized machines. In some cases all the holes can be drilled in the same jig on one machine, and the larger holes then redrilled on another machine without a jig. This eliminates the cost of one jig.

In using a fixture equipped so that several tools perform the same operation on several pieces simultaneously, the parts from each tool should be kept separate. By so doing if the product from one tool is defective, the parts will not become mixed and the trouble is more easily located and remedied. However, the additional cost of handling the parts separately may sometimes more than offset the advantage of easily locating trouble.

How far it is desirable to make a fixture adaptable to various pieces and operations is a matter of judgment in each case. It usually does not pay except where the runs are very small. In general specialization is better than adaptability because the latter, while it lessens tool expense, permits errors in settings and "monkeying" with the setup.[2]

Fixtures should be interchangeable on the various machine tools on which they can be used. Care in this particular allows greater flexibility in scheduling work through the shop. This principle calls for the standardization of slots on milling machines, machine tables, and of keys and keyways on the fixtures. So far as possible these should conform to the standards[3] adopted by The American Standards Association and sponsored by such bodies as the A.S.M.E., the National Machine Tool Builders' Association, and others.

All jigs and fixtures should be clearly marked, preferably by stamping *into* the body where it can be done, the operation, part number, etc., for which it is intended and any other information needed to identify it, also on all loose or bolted parts that may be separated from it. In very accurate fixtures stamping might be harmful. In such cases a brass plate should be screwed on, or the necessary marking may be etched.[4]

All small parts, such as clamps, special wrenches, etc., should preferably be permanently attached to the jig or fixture to prevent their being mislaid or lost.

Despite the wide variety in jigs and fixtures many details may be standardized such as bushings, latches, handles, thumbscrews, etc. This lowers costs not only by making approach to quantity production possible in the toolroom, but by making it possible to purchase them from firms specializing in such parts. It is amazing in going through large tools storages to see how many types of handles, etc., there are, differing from each other in unessential details in ways which run up costs without any compensating benefit.

The object of good fixtures is furthered by good work holders or racks for handling the work between operations. Throwing work promiscuously into tote boxes mars the finished surfaces and may cause misalignment in locating in succeeding operations.

A jig or fixture should:

(*a*) Locate the work quickly and positively
(*b*) Preclude insertion of the work in any but the position correct for cutting
(*c*) Provide rapid and positive clamping ***without undue effort***
(*d*) Allow no spring in the work, fixture, or machine table from either clamping or the pressure of the cutting tools
(*e*) Allow no slipping, vibration, or chatter during the cut
(*f*) Have ample clearance for chips, and be easily cleaned
(*g*) Allow free access and egress for cutting oil or compounds
(*h*) Be as light as is consistent with strength and rigidity, and easy to handle. In the long run the employer always pays for weariness, necessary and unnecessary. It is good design therefore to eliminate all unnecessary fatigue
(*i*) Be safe for the operator. Production should be sacrificed, if necessary, rather than have a tool which is dangerous.

SOME PRINCIPLES RELATING TO DETAILS OF DESIGN

FEEDS

The pressure due to the feed and rotation of the cutter should be against the solid part of the fixture, not against the clamp. This principle is often violated, as the wrong way is usually more convenient (Fig. 1).

In general the feed should be against the rotation of the cutter, not with it. This avoids a tendency to dig in. This has been good practice for many years. There is, however, some tendency away from this of late years.

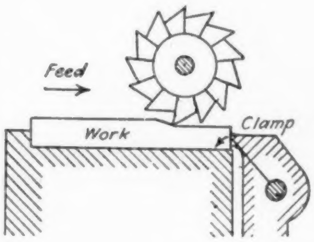


FIG. 1

Locate the feed and cuts to throw the burrs for the various cuts on the same side, to reduce burring operations as far as possible. In order to be sure that burrs do not vitiate correct setting in subsequent operations, it is wise to provide clearance grooves on locating surfaces so that burrs cannot, even if left on, interfere with correct setting.

LOCATING

Locating surfaces should be as small as is consistent with

[2] On the other hand the Western Electric Co. wherever possible designs jigs and fixtures for more than one part, and reports that the practice has given little trouble and resulted in large savings in tool expense. Errors in use have been avoided by providing wear plates which can be so located as to cover up the holes not required for the part being drilled. These plates and the jig are stamped to indicate the position of the plates for each part, so that they can be located without difficulty.

[3] The following standards applicable in this connection have been adopted by the A.S.A.:
"Shafting and Stock Keys," A.S.A.-B17-1-1934.
"T-Slots, Their Bolts, Nuts, Tongues, and Cutters," A.S.A.-B5a-1927.

[4] Mr. Hutchison, of the Western Electric Co. contributes the following: "It is not our practice to stamp tools used in the general manufacturing departments with the part number for which they are to be used. All tools are stamped with the tool number which is the same as the number of the drawing for the tool, and which is assigned consecutively from the block of numbers specified for tools. The tool number is specified on the manufacturing layout or operation sheet for the piece part made with the tool, and its use is identified in this way. A considerable number of our tools, especially those for general use, are used for a number of different parts and it would be impractical to stamp all the part numbers on the tools, especially as there would be no definite number by which the tool could be identified. Also these parts change rather often, with new ones added and others omitted, and this would mean restamping the tools, while if a specific number is assigned to the tool it is only necessary to specify this number on the layout of the new part. The only tools on which we follow the plan mentioned in the paper are some of those used in the jobbing or specialty-products department, which are usually made without drawings and are more or less temporary for parts on a customer's order basis or not made in sufficient quantities to warrant preparing manufacturing layouts or running in the regular shop departments. For a small shop where manufacturing layouts or operation sheets are not prepared and only a few tools are required, the plan of stamping the part number would probably be satisfactory, but it does not appear advisable for parts made in a large plant on a quantity productive basis, where a considerable number of different kinds of tools may be used for the manufacture of a piece of apparatus."

proper support and wear. The larger the surface, the more care and time are necessary to keep it clean and free from chips which destroy proper setting.

If a surface is to be matched in a milling operation locate from *that* surface as at *B*, Fig. 2. It may be more convenient to locate from the opposite face, but locating from the matching surface, is correct and produces better work. A variation in the thickness of even a half of a thousandth will show, although it may not affect the operation of the piece.

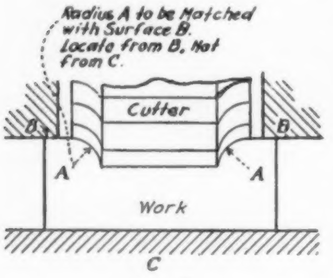


FIG. 2

Avoid sharp corners between locating surfaces. They catch dust and dirt and are hard to clean (Fig. 3).

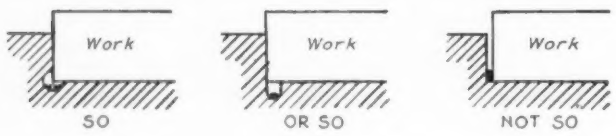


FIG. 3

The number of fixed supports should not be more than three. These should be as far apart as possible. If other supports are needed they should have only spring tension against the work during clamping and be locked in position after the work is set.

It should be easy to keep the locating surfaces clean, therefore, there should be ample clearance for chips. If possible accumulated chips should fall away from, rather than on to the locating surfaces when the work is removed. If possible keep the locating surfaces completely covered by the work, so that chips cannot collect on them.

All the locating surfaces of a jig or fixture should be fixed. Movable surfaces should be used for clamping only.

Buttons or pins, hardened and ground, are often better for locating than flat surfaces as they are easier to keep clean and afford easier adjustment for wear. They are better when acting endwise than sidewise, as there is no bending action and they are more readily set up for wear (Fig. 4).

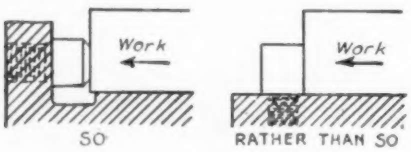


FIG. 4

It is better to support castings on buttons or pins than on flat surfaces. They position better and more definitely. Surfaces which locate drop forgings should have clearance for the flash, and preferably should be located from one side of the flash only, as the dies which made the forging may not have been exactly matched. Locating from the upper side of the forging, or the side which is above the flash, is preferable parctice.

The clamping should not produce any horizontal sliding action across the locating faces as this causes wear.

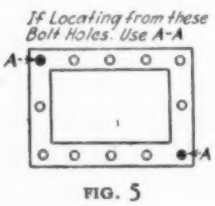


FIG. 5

Locating and supporting points should be as far apart as the nature of the work will allow (Fig. 5).

The locating and support points should be visible and easily accessible to the operator.

Do not stack pieces one against another, if accuracy is required. In multiple work each piece should be located independently against fixed stops. In well-designed fixtures this is done, although several pieces may be clamped by one motion.

In multiple milling fixtures do not mill the pieces serially, with a single cutter, if the runs are long. Use multiple cutters, one for each piece and feed across the row. This reduces the length of feed and therefore the cutting time. This applies, of course, to fixtures with a reciprocating feed, not to those with rotary continuous feeds.

Parts of the fixture requiring accurate location should be held by screws and dowels or splines. The screws should not have to perform the double function of locating and holding (Fig. 6).

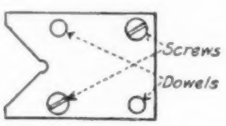


FIG. 6

When locating blocks are assembled into fixtures it is sometimes desirable to arrange the screws and dowels as shown in Fig. 7. When arranged this way, the contacting surface only is hardened, leaving the section carrying the dowel pins soft, so that the reaming of the holes and the alignment of the piece can be done after hardening.

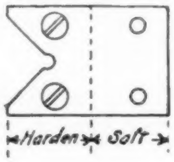


FIG. 7

Where the positioning need be only in one direction, the side of the piece or preferably a tongue and groove may be used for locating, and the screws go through slotted holes (Fig. 8).

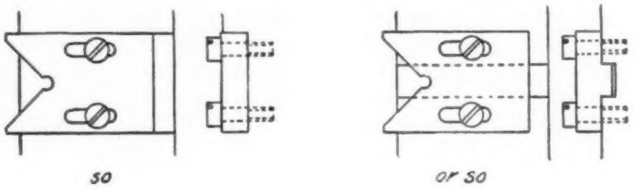


FIG. 8

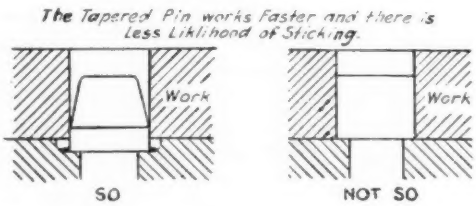


FIG. 9

If position pins are used for locating a previously drilled hole, that portion which is full diameter should be as short as is consistent with wear, and the rest or upper part of the pin tapering (Fig. 9).

Locating pins should be hardened and ground with clearance for burrs and chips. When used with counterbored holes they should center on only one diameter.

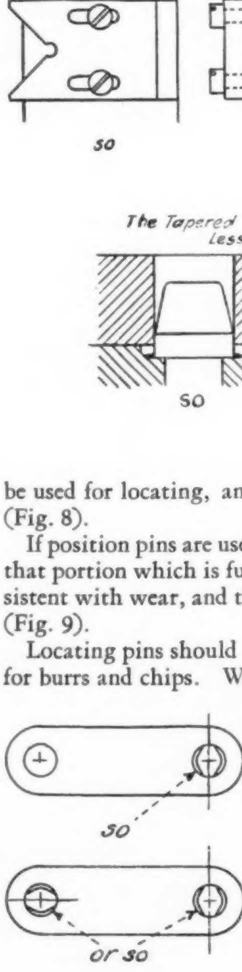


FIG. 10

When two pins are used for locating, one should be flattened on the sides toward and away from the other pin (Fig. 10). Sometimes it is desirable to flatten both pins, the plane of the flattening being at 90 deg as shown in the lower figure.

If one pin is higher than the other, preferably the larger one, the work can be seated more rapidly.

CLAMPING

Under no circumstances should the line of clamping pressure come above the stop. If it did there would be a tendency to lift the work. Side clamps should press downward as well as inward (see Fig. 1). By so doing the clamping tends to seat the work.

The clamp should be immediately opposite the supporting point, with solid metal between. Disregard of this leads to springing the work, or lifting of the work due to the support acting as a fulcrum (Fig. 11).

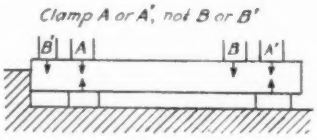


FIG. 11

Clamps and adjusting points should be operated from the front or working side of the fixture as illustrated in Fig. 12.

The tool thrust should be taken up by an adequate, fixed stop, not by the friction between the work and the clamp. Clamping

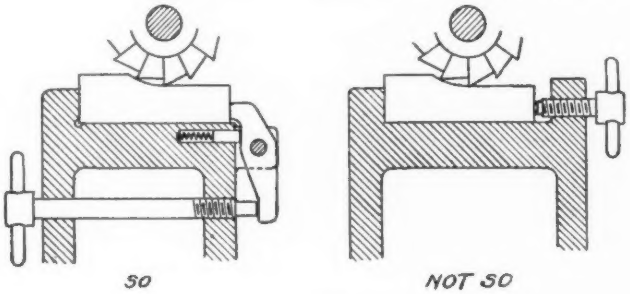


FIG. 12

jaws should, if possible, be at right angles to the direction of the cut, not parallel to it.

All the clamping strain should be cared for within the fixture itself. None of it should be transmitted to the table of the machine.

Cams or wedges, if used for clamping, should be so designed that the pressure and feed tend to tighten them, not to loosen them.

Clamps should have springs and washers under them so that the operator will not have to hold them back while inserting the work (Fig. 13). A better form, with the spring concealed so that chips can not interfere with it, is shown in Fig. 14.

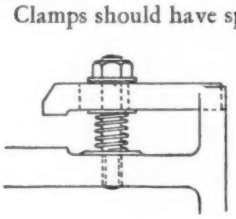


FIG. 13

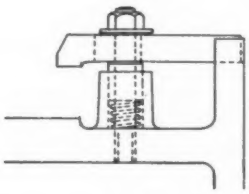


FIG. 14

To save time in loading and unloading a fixture, clamps which have considerable motion should, in order to clear the work, have a rapid action when free from the work and a slow motion with increased power when they are brought into contact with it. A variety of devices are available, such as the toggle-joint, bayonet screw, interrupted thread, slotted clamp, etc.

Clamps holding casting and irregularly shaped surfaces should be on the floating principle to enable them to adapt themselves to the shape of the work.

JIG LEGS

The center of gravity of the jig, with the work in it, and also the thrust of the drill should lie within the geometrical figure formed by the supports. This avoids a tendency for the jig to lift or tip.

A drilling jig should have *four* legs. With a three-legged support, it will rest stable on any surface. If a chip is under one leg of a three-legged support the fact will not be detected. With a four-legged support the jig will teeter if it is on an uneven surface or a chip is under one of the supports.

Supporting strips or lugs are sometimes better than legs as they are less likely to drop into T-slots or holes in the machine table.

JIG BUSHINGS

Loose or screwed-in solid bushings should not be used where accuracy is important. Where screwed-in bushings are necessary they should center on cylindrical surfaces, not on the threads.

The length of bearing for the drill should, in fixed bushings, be about $1^1/_2$ to 2 times the diameter of the drill; in slip bushing about 2 to 3 times the diameter of the drill. If the bushing is longer than this, the remainder of the length farthest from the work may be relieved.

Bushings should not be located close to the work with the object of carrying the chips up through the bushing except when the holes to be drilled are in a machined face which is clamped against a similar face in the jig. It is better, when the design will permit, to allow the chips to clear between the work and the bushing. About one drill diameter is usually sufficient. For small holes where great accuracy is required the bushing should be brought down close to the work. For drills smaller than No. 31 this dimension may be approximately $^1/_{64}$ in. with drills ground with a flat point.

JIG LATCHES

In the joint of a latch give the latch the widest possible hold on the hinge pin (Fig. 15).

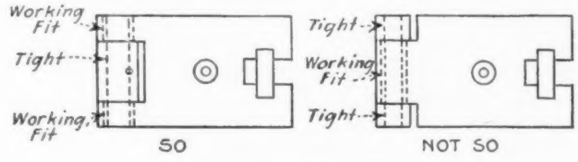


FIG. 15

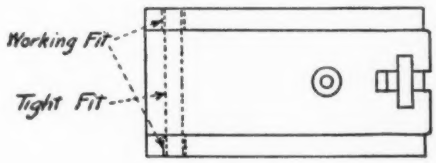


FIG. 16

A still better type of latch is shown in Fig. 16, which gives better side support when in working position. If possible avoid placing clamps in a latch which carries drill bushings, as any clamping pressure has a tendency to spring the latch and throw the bushings out of alignment.

Preferably a jig latch should have a support or stop to hold it when it is thrown back. This lessens the possibility of misalignment through use.

It may be of advantage to have the hinge pin tapered. This permits readier adjustment for wear, etc.

GENERAL

Thumb nuts, fluted nuts, and levers should be used where the quantities are large, as the necessity of handling wrenches is thus avoided. They should be large enough to give the re-

quired pressure easily. When it becomes necessary for an operator to use a mallet, time is lost and either the work or the fixture is likely to be sprung.

Thumb nuts and hand knobs should have ample clearance around them to permit their being manipulated properly and to avoid possibility of injury. Avoid knurling nuts and handles. When covered with cutting lubricant they are irritating to the operator's hands under constant use.

If it is necessary to use a wrench in setting the work the various nuts should preferably be of the same size, so that change of wrenches is not necessary.

All exposed screws, nuts, and lugs, the motion of which might catch the operator, are to be avoided, and all sharp corners and edges should be removed.

The operator's hands must be well clear of the cutters during the insertion, clamping, and removal of the work.

There should be no danger of destruction of the work, tool, fixture, or machine through the overrunning of the cutter.

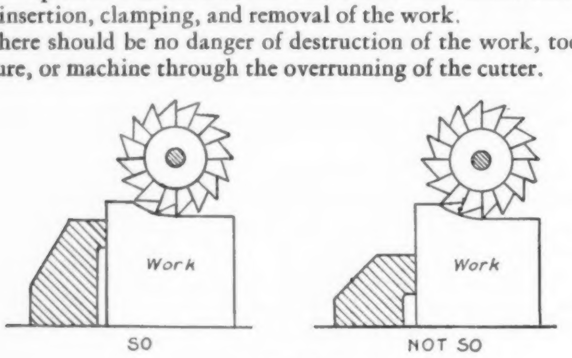


FIG. 17

It is desirable to have the cutting zone as close to the machine table as possible. If, for some good reason it must be high, then the surface taking the thrust of the cut should be high, i.e., as nearly in line with the cut as possible (Fig. 17).

It is desirable that parts subject to wear be renewable without destroying the jig or fixture.

* * *

[Reprints of the foregoing paper are soon to be available for sale. These reprints will carry an extended bibliography. —EDITOR.]

The Mechanical Development of a Wood-Briquetting Machine

(Continued from page 108)

manual controls. These controls consist of the latest and best types obtainable. The controls operate 2500 to 3000 times per day.

The total connected load of the machine is $65^3/_4$ hp; 50 hp of this being required to drive the pressing screw and tip forming head; 15 hp to drive the index oil pump, and $^3/_4$ hp on the yielding-pressure-control cylinder. A total of 65 kwhr is required to make one ton of briquettes. Capacity of machine is 12 tons of briquettes per day of 24 hr.

PLANTS FOR MAKING BRIQUETTES

A briquette-machine plant requires other equipment than the briquette machine only. Usually, buildings or space in an existing woodworking plant are available to install a briquette machine, but auxiliary equipment such as conveyers, grinders, and fuel bins must be provided. The cost of making briquettes varies with the cost of labor, power, number of machines being operated, and other factors in any given locality.

Briquettes have been made of practically all common species of wood, and some that are not common. All of them make good briquettes with the proper adjustment of pressing screws and tips. Briquettes have also been made from a great variety of fibrous and nonfibrous materials other than wood, such as wheat and pea straw, alfalfa, sugar-beet pulp, almond shells, peach pits, common salt, and many others.

To date there are 35 machines installed in Idaho, Washington, Oregon, California, and Nevada and one in South Africa. These machines have an annual production capacity of 140,000 tons.

Up to the present only one size of briquette has been placed on the market. This particular size in the form of a small log was used because it was easy to handle, and most economical from the viewpoint of production. Experiments are now being carried out to make small briquettes suitable for firing domestic and commercial stokers. The success of these experiments would broaden the field of usefulness of wood-briquetting machines.

Quantity Production of Gyro Instruments

(Continued from page 100)

parts manufacture repays us in assembly. During expansion, assemblers can be trained more quickly and the results give more uniformity in the product.

No matter how precisely the parts have been manufactured and how perfectly the assembly has been made, however, the resulting aggregation is not a gyro instrument. It yet has to be balanced, calibrated and tested before it performs properly the functions for which it was made. In spite of all the precision which has been attained dimensionally and by measurement, the final performance depends upon yet finer adjustments which cannot be measured directly but can only be indicated by the change in performance of the instrument. This calibrating and balancing, at first one of the most difficult jobs, has slowly been brought down to routine procedure where it is now efficiently accomplished by girls.

We do not subcontract any of the assembly work, but carry out all assembly, calibration, and test under our own supervision. As the rate of production has increased, we have had to expand the assembly department very rapidly. This has not been difficult. It does not involve purchasing machine tools but only benches, small tools and testing apparatus. We recently outgrew the available space in our own building and moved the entire instrument-assembly department into another near-by building. The move was not difficult and did not noticeably interfere with production. We are now in a position to expand still further with no disturbance.

SUMMARY

The case of gyro-instrument emergency production has been stated to show one way successfully to meet and accelerate production programs. It demonstrates the possibility of applying the M-Day plan even to the most difficult and precise machining and instrument work. By putting this scheme into operation, we have increased the rate of production of these instruments 800 per cent in the last year, without any sacrifice in the quality or performance of the instruments. The unique part of our method is the extent to which we have carried the educational features in preparing our subcontractors for our work. This scheme has required 2 or 3 years of advance planning but, fortunately, with this behind us we have been able to expand the production as rapidly as the pyramiding orders have been received. The rate of production can be maintained at any desired figure during the emergency and then contracted without the wastefulness of having large quantities of unused machine tools and facilities.

INTERNATIONAL TRADE RELATIONS AFTER THE WAR[1]

By RALPH E. FREEMAN

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE Utopia to which nineteenth-century liberals clung, that economic activity was best organized by private enterprise operating on a world-wide scale, with the barest minimum of government regulation and intervention, has been rejected." The story of this rejection is told by J. B. Condliffe in a comprehensive survey of international economic relations.[2] He tells the story of the efforts that were made after the previous war to restore the international trading system on the prewar model, and he explains why those efforts failed. Two principal reasons are given: First, that international policies were dictated by concern for national interests with scant regard for mutual interdependence and reliance on expanding world markets; and second, that national interest in the sense of the welfare of the people became subordinated to the interest of the state itself. The purposes of the state have come more and more to take precedence over those of the community it exists to serve. In some countries these purposes have been the achievement of social ends through various forms of national planning, in others the purposes have been the aggrandizement of political groups which have gained control of the state.

The means by which the international system was wrecked are outlined by Mr. Condliffe. The increase of tariffs and the collapse of the international capital market threatened the stability of various currencies and led to the imposition of additional restrictions on the movement of goods. Quota systems, exchange controls, and clearing agreements placed further restraints upon international commerce. The raising of barriers by one nation provoked retaliation by others and thus the restrictive system spread till world trade had shrunk to small proportions. Finally in 1931, there was the great liquidity panic which forced Great Britain off the gold standard, and carried the currencies of many other nations into various degrees of depreciation.

The system of trade restriction which at first was negative in character developed in many countries a positive momentum. When the worst of the depression was over, government intervention in foreign trade, which had up to that time been defensive, became an offensive weapon in the hands of aggressive states. Exchange control became the means by which the national market was segregated and all external trade directed into the channels desired by government policy. By this means the national economic activity of Germany was mobilized for war. Capital was not allowed to pass over the frontiers and individuals were not permitted to engage in any import or export transactions that would weaken the military power of the nation.

When the world monetary and trading system broke down under the impact of the depression, attempts were made to restore international commerce through the negotiation of commercial treaties involving a balancing of trade between pairs of countries. This balancing was effected by means of the clearing agreement whereby funds derived from goods sold by one country to another were available to the former only for the purchase of the latter's goods. Whatever may be said in support of this bilateralism as a device to cope with an emergency situation, it cannot be commended as a permanent policy. It eliminates trade arrangements by which one country settles an import surplus with a second country, by transferring to the latter the proceeds of its export surplus with a third. Since a great deal of the most profitable trade of the world has been of this character, the bilateral balancing of trade between pairs of countries means a permanent reduction in the volume of international exchanges. In recent years, however, these bilateral agreements have been greatly developed. Their scope has been widened to include not only commodity trade but other international payments such as those for debt service, shipping freights, insurance, and tourist traffic. They have also taken on aggressive aspects; they have been used as means of destroying the trade of some nations and of dominating the economic life of others. The Balkan countries, for example, dependent upon Germany for markets for their raw materials, have been forced to utilize the proceeds of their sales to Germany for the purchase of German goods. As Mr. Condliffe explains, this system had, even before the war, impaired the economic sovereignty of the Balkan countries "by forcing them to accept a measure of German advice and control in the organization of their economic activity and by necessitating their acceptance of economic regulation modeled upon and fitted into the German system. It would not require much extension of such dominance to impair their political independence and place them in a position of economic satellites dependent upon, and serving the purposes of, the German market upon Germany's own terms" (p. 294).

Mr. Condliffe does not expect to see the return of the old international system after the present war. The type of reconstruction attempted after the war of 1914–1918 was based primarily upon the principle of self-determination with the assumption that a world of independent sovereign states great and small could find means of economic cooperation reconciling nationality with the necessity of world-wide specialization and exchange. That assumption was falsified in the 20 years that followed. It is even less justified now that economic activity is not merely directed by but has come to be a part of government organization. He predicts the creation of great economic regions (Germany, Russia, Japan, the British Empire, United States) surrounded by subordinate areas enjoying varying degrees of political autonomy but essentially dependent upon the financial, monetary, and economic strength of the dominant power.

In the event of a German victory the author sees the formation of great autarchic empires whose economic and political rivalry will lay the foundations of ever more devastating wars. "No great industrial country can afford to remain dependent on the good will of its rivals for access to essential supplies of minerals and oil. These supplies are so scattered over the earth's surface that there are no other alternatives open than a con-

(*Continued on page 134*)

[1] One of a series of reviews of current economic literature affecting engineering, prepared by members of the department of economics and social science, the Massachusetts Institute of Technology, at the request of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Opinions expressed are those of the reviewer.

[2] "The Reconstruction of World Trade," by J. B. Condliffe, New York, N. Y. W. W. Norton, 1940, 427 pages.

THE NEW SPECIFIC HEATS

Addenda to and Discussion of Paper by R. C. H. Heck

IN THE January, 1940, issue of MECHANICAL ENGINEERING, Robert C. H. Heck, research professor of mechanical engineering, Rutgers University, New Brunswick, N. J., contributed a paper, which was presented at the A.S.M.E. Spring Meeting, at Worcester, Mass., May 1–3, 1940, under the same title as here given. The purpose of this paper was to explain the development and use of a radically different method of determining the thermal properties of gases. After presenting an outline description of methods, illustrated by curves, the results of the research were given in the form of numerical tables. Data supplementary to the original paper are contained in the addenda herewith, following which the discussion of the paper appears.

Addenda

RELATIONS AND METHODS

The conclusions of the older kinetic theory of gases, as represented by horizontals 5, 7, and 8 in Fig. 1 of the paper, were reasoned for the molecule as a rigid body or structure. Atoms were conceived as tiny hard balls, held in contact by rigid bonds; the words "hard" and "rigid" imply a high modulus of elasticity, with small deformation during impact and very short time of impact. The single atom is then so small that any energy of spin will also be very small relative to kinetic energy of translation. Furthermore, we must postulate tangential-surface friction in order to get spin change by glancing impact. The later simple concept of the very minute high-density nucleus, surrounded by what is probably a spherical field of force which functions as an elastic cushion of low modulus, yields an atom which continues the idea of low spin energy; and by holding the nuclei farther apart it enlarges the idea of spin energy of the molecule.

Through the impact of simple, single, perfectly elastic balls there is no change in total kinetic energy due to linear velocities of mass centers. But in the impact of congeries of such spherical bodies, with probable change of spin motions of both systems, there will be change in the combined kinetic energy of translation. The kinetic theory deals then with the following geometrical setup:

The single atom or the center of mass of the compounded molecule is positioned by three linear rectangular coordinates.

The two-atom molecule, a linear body, is further completely positioned by angles with two coordinate planes.

TABLE 6 AIR AS A MIXTURE

Gas	Vol	M	MV	Wt	Vol	Wt
O_2	0.2083	32	6.666	0.230	1.00	1.000
N_2	0.7817	28.02	21.903	0.756	3.80	3.345
A	0.0100	40	0.400	0.014		
	1.0000		28.97	1.000	4.80	4.345
	1	2	3	4	5	6

1 Volume composition, including argon; also mol numbers.
2 Molecular weights or mol weights.
3 Weights of mol ingredients, also mean mol weight.
4 Weight composition, from 3.
5,6 Volume and weight ratios to oxygen, lumping N_2 and A as atmospheric nitrogen, which has the mol weight 28.17.

The gas constant for our engineering units is $R = 1544 \div 28.97 = 53.3$, with $R/144 = 0.3702$ for pressure in psi.

The three-atom molecule, a plane triangle, requires a third angular coordinate; and this is all that is needed for a more elaborate, probably three-dimensional system.

Variations of the three or five or six positioning coordinates are the degrees of freedom of molecular motion.

Making elaborate use of statistical mathematics, the kinetic theory concludes that energy components due to the degrees of freedom are equal in size, or that there is equipartition of energy among the three or five or six components of motion of the vast

TABLE 7 THERMAL PROPERTIES OF PURE DRY AIR

T deg R	c_p	c_v	γ	h	u
600	0.2406	0.1721	1.398	14.4	10.3
700	0.2418	0.1733	1.395	38.5	27.6
800	0.2436	0.1751	1.391	62.8	45.0
900	0.2460	0.1775	1.386	87.3	62.6
1000	0.2488	0.1803	1.380	112.0	80.5
1100	0.2518	0.1833	1.374	137.1	98.7
1200	0.2549	0.1864	1.368	162.4	117.2
1300	0.2581	0.1896	1.361	188.1	136.0
1400	0.2613	0.1928	1.355	214.1	155.1
1500	0.2644	0.1959	1.350	240.3	174.5
1600	0.2673	0.1988	1.345	266.8	194.2
1700	0.2701	0.2016	1.340	293.7	214.2
1800	0.2727	0.2042	1.336	320.9	234.5
1900	0.2752	0.2067	1.332	348.4	255.1
2000	0.2775	0.2090	1.328	376.0	275.9
2100	0.2796	0.2111	1.325	403.8	297.0
2200	0.2815	0.2130	1.322	431.8	318.2
2300	0.2833	0.2148	1.319	460.0	339.6
2400	0.2850	0.2165	1.317	488.4	361.1
2500	0.2866	0.2181	1.314	517.0	382.8
2600	0.2881	0.2195	1.312	545.8	404.7
2700	0.2894	0.2209	1.310	574.7	426.7
2800	0.2907	0.2222	1.308	603.7	448.9
2900	0.2920	0.2234	1.307	632.8	471.1
3000	0.2931	0.2246	1.305	662.1	493.5
3100	0.2942	0.2257	1.304	691.5	516.0
3200	0.2952	0.2267	1.302	720.9	538.7
3300	0.2962	0.2276	1.301	750.5	561.5
3400	0.2971	0.2285	1.300	780.2	584.3
3500	0.2980	0.2294	1.299	810.0	607.2
3600	0.2988	0.2303	1.298	839.8	630.2
3700	0.2996	0.2311	1.297	869.7	653.2
3800	0.3004	0.2318	1.296	899.7	676.4
3900	0.3011	0.2325	1.295	929.8	699.6
4000	0.3018	0.2333	1.294	960.0	722.9
4100	0.3025	0.2340	1.293	990.2	746.3
4200	0.3031	0.2346	1.292	1020.5	769.7
4300	0.3037	0.2352	1.291	1050.8	793.2
4400	0.3043	0.2358	1.291	1081.2	816.7
4500	0.3049	0.2364	1.290	1111.7	840.3
4600	0.3055	0.2369	1.289	1142.2	864.0
4700	0.3060	0.2375	1.289	1172.8	887.7
4800	0.3065	0.2380	1.288	1203.4	911.5
4900	0.3070	0.2385	1.287	1234.1	935.3
5000	0.3075	0.2389	1.287	1264.8	959.2
5100	0.3079	0.2394	1.286	1295.6	983.1
5200	0.3084	0.2399	1.286	1326.4	1007.1
5300	0.3088	0.2403	1.285	1357.2	1031.1
5400	0.3093	0.2407	1.285	1388.1	1055.1
5500	0.3097	0.2411	1.285	1419.1	1079.2

Table 7 is like Tables 1 to 3 in being based on temperature Rankine or Fahrenheit absolute. The two specific heats per pound are given, with their ratio $c_p/c_v = \gamma$. Heat content or enthalpy h, and energy u, in Btu per lb are above the state of gas at 540 R or 80 F. For argon the constant specific heat $2.5\ R = 4.962$ is used.

TABLE 8 EXAMPLE A: REPRESENTING BITUMINOUS COAL

	Wt	Ratio	Oxy	Prod	wt	M	Mol	Vol
C	0.95 ×	2.667 =	2.533	CO_2	3.483 ÷	44	= 0.07916	0.1465
H_2	0.05 ×	8 =	0.400	H_2O	0.450 ÷	18	= 0.02500	0.0463
		Net O_2	2.933	N_2	11.774 ÷	28.17	= 0.41796	0.7733
3.345		Net N_2	9.812	O_2	0.587 ÷	32	= 0.01834	0.0339
		Net air	12.745		16.295		0.54046	1.0000

Excess air, 20 per cent. Mol wt, M = 16.294 ÷ 0.54046 = 30.148

TABLE 9 EXAMPLE B: REPRESENTING LIGHT OIL

	Wt	Ratio	Oxy	Prod	wt	M	Mol	Vol
C	0.85 ×	2.667 =	2.267	CO_2	3.117 ÷	44	= 0.07083	0.1071
H_2	0.15 ×	8 =	1.200	H_2O	1.350 ÷	18	= 0.07500	0.1134
		Net O_2	3.467	N_2	13.915 ÷	28.17	= 0.49397	0.7468
3.345		Net N_2	11.596	O_2	0.693 ÷	32	= 0.02166	0.0327
		Net air	15.063		19.075		0.66146	1.0000

Excess air, 20 per cent. Mol wt, M = 19.075 ÷ 0.66146 = 28.84

TABLE 10 COMPARISON OF MOL HEAT CONTENTS H

T	A	B	Diff	T	A	B	Diff
1000	3467	3448	− 19	3500	25784	25644	−140
1500	7512	7457	− 55	4000	30627	30489	−138
2000	11831	11740	− 71	4500	35526	35398	−128
2500	16353	16235	−118	5000	40469	40354	−115
3000	21017	20882	−135	5500	45646	45354	− 92

number of molecules in even a minute portion of gas-occupied space.

In this connection, it may be of interest to get some idea of molecule number and size. The physicists have very definitely established the number 6.026 × 10^{23} molecules per g-mol. For a gas (any gas) at ice-point temperature and under standard atmospheric pressure, this reduces to 27,000,000 molecules per cu μ, the value of μ being 0.001 mm or $^1/_{25400}$ in. The space assignable to one molecule is then represented by a cube of which the side is $^1/_{300}$ μ or 3.3 mμ. The "diameter" of the simpler gas molecule is roughly known as about one tenth the side of that cube.

Going back to the equipartition of energy with rigid molecules, constant C_p is represented by lines 5, 7, or 8 above the base of Fig. 1, constant C_v by the same lines above line 2. The unit to which these numbers apply is 0.5 R or 0.9925, for the mol of gas.

Whether determined in the old way, by direct experiment, or in the more effective new way, the rise of real heat capacity above the primary horizontals must be due to energies within the molecule. The most obvious component of such internal energy is the energy of oscillation of the atoms within the range of their elastic bonds; but the full theory goes inside the atom, to consider energy of the electrons and even spin of the nucleus.

Now the mean molecular velocity (or, more strictly, velocity squared), which enters into the concept of temperature as well as into energy quantity, is the average of a wide range of individual velocities; the range being perhaps from one fourth to four times the mean. In other words, a body of gas at any temperature contains numbers of molecules at differrent energy levels; but in this simple concept the number of such levels approaches infinity.

Now comes the new method, a twentieth-century development, which rises in and from the quantum theory. By close and elaborate analysis, it establishes the principle of a limited number of definite and distinct energy levels. The second working principle is that the proportional numbers of molecules at particular energy levels can be determined by spectroscopic observation and measurement.

Anything further on this matter is out of place here. Probably the best general reference is to two books[1] by Gerhard Herzberg, now at the University of Saskatchewan, where they were tranlsated by J. W. T. Spinks.

As to the shape of the curves in Fig. 1 of the paper, it was formerly the opinion that the dotted D and H_2O curves (with increasing upswing) were normal in form, while the CO_2 curve seemed anomalous. Now it appears that the latter form is correct and general. As to truth and accuracy, the new determinations seem to be worthy of full confidence.

As to the section of the paper on low-range behavior, the present purpose is chiefly to make clear the fact that there is a large fund of definite knowledge in that region.

[1] "Atomic Spectra and Atomic Structure," by Gerhard Herzberg, translated by J. W. T. Spinks, 1937; and "Molecular Spectra and Moecular Structure," 1939, Prentice-Hall, New York, N. Y.

TABLE 11 TYPICAL COMBUSTION GASES

	A		A		B	
T deg R	H	U	h	u	h	u
600	440	321	14.6	10.6	15.2	11.1
700	1181	863	39.2	28.6	40.8	29.8
800	1932	1415	64.1	47.0	66.7	48.8
900	2693	1978	89.3	65.6	93.0	68.2
1000	3467	2553	115.0	84.7	119.6	87.9
1100	4252	3141	141.1	104.2	146.6	108.0
1200	5050	3740	167.5	124.0	174.0	128.5
1300	5859	4351	194.3	144.3	201.8	149.4
1400	6680	4973	221.6	165.0	230.0	170.8
1500	7512	5606	249.2	186.0	258.6	192.5
1600	8354	6250	277.1	207.3	287.5	214.6
1700	9209	6906	305.4	229.0	316.9	237.1
1800	10074	7573	334.1	251.2	346.6	259.9
1900	10948	8249	363.2	273.6	376.7	283.1
2000	11831	8933	392.5	296.3	407.1	306.6
2100	12722	9626	422.0	319.3	437.8	330.4
2200	13620	10325	451.8	342.5	468.7	354.4
2300	14525	11031	481.8	365.9	499.9	378.7
2400	15436	11744	512.0	389.5	531.3	403.2
2500	16353	12462	542.4	413.3	562.9	428.0
2600	17276	13187	573.0	437.4	594.8	453.0
2700	18204	13916	603.8	461.6	626.8	478.2
2800	19137	14651	634.8	486.0	659.1	503.5
2900	20075	15390	665.9	510.5	691.5	529.0
3000	21017	16134	697.1	535.2	724.1	554.7
3100	21963	16882	728.5	560.0	756.8	580.6
3200	22913	17633	760.0	584.9	789.7	606.6
3300	23867	18385	791.7	609.9	822.7	632.8
3400	24824	19147	823.4	635.1	855.9	659.1
3500	25784	19909	855.3	660.4	889.2	685.4
3600	26747	20673	887.2	685.8	922.6	711.9
3700	27713	21440	919.2	711.2	956.1	738.6
3800	28682	22210	951.4	736.7	989.7	765.1
3900	29653	22983	983.6	762.3	1023.4	792.1
4000	30627	23759	1015.9	788.0	1057.2	819.0
4100	31602	24536	1048.3	813.8	1091.1	846.0
4200	32580	25115	1080.7	839.7	1125.0	873.1
4300	33560	26096	1113.2	865.6	1159.1	900.3
4400	34542	26879	1145.8	891.6	1193.2	927.5
4500	35525	27664	1178.4	917.6	1227.4	954.2
4600	36570	28450	1211.1	943.7	1261.6	982.2
4700	37497	29239	1243.8	969.9	1295.9	1009.6
4800	38486	30030	1276.6	996.1	1330.3	1037.1
4900	39477	30822	1309.5	1022.4	1364.7	1064.6
5000	40469	31615	1342.4	1048.7	1399.2	1092.2
5100	41462	32411	1375.3	1075.1	1433.8	1119.9
5200	42456	33207	1408.3	1101.5	1468.4	1147.7
5300	43452	34003	1441.3	1127.9	1503.1	1175.5
5400	44448	34801	1474.4	1154.4	1537.8	1203.3
5500	45446	35600	1507.5	1180.9	1572.6	1231.2

SUPPLEMENTARY INFORMATION

In furtherance of the purpose of practical utility, two full-range tables are appended, with auxiliary data. The first, Table 7, is for 1 lb of air; the second, Table 11, is for an average products-of-combustion mixture and is given in order to facilitate the use of Tables 1 to 3 of the paper. The frequent use of those tables will be to answer, for any particular gas mixture, the question, "What is the value of h or u at any given temperature?" or "What temperature corresponds to a given h or u?"

The computation of a table of the character of Table 7 is a simple but laborious task. In order to make Tables 1 to 3 more practically useful, the scheme is now proposed of a mean-gas table which will serve as a guide or indicator. Two typical examples are chosen of the weight proportions of pure carbon-hydrogen fuel, as in the first columns of Tables 8 and 9. Then by a calculation which is shown in condensed outline, these are brought to weight and volume proportions of combustion products, with moderate excess air. To see by how much they differ, their mol heat contents are compared in Table 10, showing H in case B smaller than in case A by a fraction of 1 per cent; but because of lower density (smaller mol weight) in case B its pound-heats run larger.

Table 11 should be self-evident as to form and meaning. Only one set of mol heats is included, but pound-heats are given for both mixtures. These are carried to the nearest 0.1 Btu, in order that specific heats may be seen with fair accuracy by taking table differences. With Table 11 as a guide, answers to either of the heat-and-temperature questions proposed previously can be made by means of two or three 100-deg calculations for the particular mixture which may be in question.

Discussion

J. W. MAY INDICATES DIFFICULTY IN CHECKING TABLES

J. W. May[2] discussed the paper as follows: The tabulated results do not readily lend themselves to being checked as the values of specific heat are apparently based on empirical data gathered from other sources (see references in paper) and the results can only be as accurate, of course, as the original data. Assuming the original data to be correct, it would be difficult to check the tabulated values as it would be necessary in each case to use the same three-point spread as was used by the author for substituting in the equation of a parabola. The same difficulty arises in attempting to check the values as given for the heat content H at the different temperatures, as this requires the equation for determining the specific heat for the temperature in question. The values for the internal energy U come directly from H, as indicated by the author. The relation used is, of course, not strictly true for imperfect gases.

As indicated in the paper, the equations given in Marks's Handbook for the specific heat (at constant pressure) of different gases give results which are considerably different from those of the author. However, V. M. Faires[3] gives values which approach more closely those of the paper. The equations given by Professor Faires were taken from the work[4] by Spencer and Justice. The statement is made that the equations are suitably accurate for temperatures of from 500 R to 2700 R.

Table 12 of this discussion will illustrate the differences in the value of C_p, as given by the three sources previously mentioned.

[2] Associate Professor of Heating and Ventilating, University of Kentucky, Lexington, Ky.

M. W. BEARDSLEY DISCUSSES FULL-RANGE FORMULAS

M. W. Beardsley[5] commented as follows: The author's calculated values of C_p and H are in excellent agreement with the original values computed from spectroscopic data, and by publishing his equations he could contribute valuable information for use in calculations where more than ordinary accuracy is required.

[3] "Applied Thermodynamics," by V. M. Faires, The Macmillan Company, New York, N. Y., 1938.

[4] "Empirical Heat-Capacity Equations for Simple Gases," by H. M. Spencer and J. L. Justice, *Journal of the American Chemical Society*, vol. 56, 1934, pp. 2311–2312.

[5] State Engineering Experiment Station, Georgia School of Technology, Atlanta, Ga.

TABLE 12 SPECIFIC HEAT—C_p—BTU PER LB MOL

		Spencer and Justice			Marks's Handbook	
	T deg R	Tabulated values by author	Calculated from equations	Variation based on author's values, per cent	Calculated from equations	Variation based on author's values, per cent
Oxygen O_2	600	7.075	7.071	−0.056	6.975	− 1.41
	1000	7.570	7.593	+0.304	7.055	− 6.80
	1500	8.119	8.104	−0.184	7.212	−11.19
	2000	8.452	8.458	+0.071	7.432	−12.05
	2500	8.669	8.655	−0.161	7.714	−10.56
Hydrogen H_2	600	6.933	6.937	+0.057	6.975	+ 0.61
	1000	7.001	6.987	−0.200	7.055	+ 0.77
	1500	7.096	7.117	+0.296	7.212	+ 1.64
	2000	7.323	7.322	−0.014	7.432	+ 1.49
	2500	7.600	7.600	0.0	7.714	+ 1.50

Spencer and Justice $\begin{cases} O_2 - C_p = 6.1 + 18.07\, T/10^4 - 31.4\, T^2/10^8 \\ H_2 - C_p = 6.95 - 1.11\, T/10^4 + 14.84\, T^2/10^8 \end{cases}$

Marks's Handbook gives one equation for all diatomic gases

$$C_p = 6.93 + 0.1254 \left(\frac{T}{1000}\right)^2$$

NOTE: An upper limit of 2500 R was chosen because of the reason previously mentioned concerning the suitability of Spencer and Justice's equation.[4]

TABLE 13 VALUES OF C_p AND H, CALCULATED BY FULL-RANGE EQUATIONS[6]

N_2:

$$C_p = 9.47 - \frac{3470}{T} + \frac{1.16 \times 10^6}{T^2}$$

$$H = 9.47T - 3470 \ln T - \frac{1.16 \times 10^6}{T}$$

CO_2:

$$C_p = 16.2 - \frac{6530}{T} + \frac{1.41 \times 10^6}{T^2}$$

$$H = 16.2T - 6530 \ln T - \frac{1.41 \times 10^6}{T}$$

N_2 C_p Eq	N_2 C_p Heck	N_2 H Eq	N_2 H Heck	T deg R	CO_2 C_p Eq	CO_2 C_p Heck	CO_2 H Eq	CO_2 H Heck
6.909	6.968	435	418	600	9.235	9.283	530	547
7.160	7.140	3195	3231	1000	11.080	11.049	4650	4637
7.674	7.571	6932	6905	1500	12.476	12.445	10570	10538
8.025	7.971	10845	10795	2000	13.286	13.298	17055	16994
8.268	8.247	14961	14853	2500	13.813	13.839	23796	23785
8.442	8.444	19128	19028	3000	14.182	14.205	30790	30803
8.574	8.581	23374	23287	3500	14.449	14.460	37937	37975
8.675	8.684	27675	27605	4000	14.655	14.644	45288	45253
8.756	8.761	32057	31967	4500	14.729	14.797	52597	52614
8.822	8.820	36443	36364	5000	14.910	14.922	60078	60045
8.867	8.860	39950	39898	5400	15.038	15.003	66099	66030

[6] "Empirical Specific-Heat Equations Based Upon Spectroscopic Data," by R. L. Sweigert and M. W. Beardsley, Bulletin No. 2, Georgia State Engineering Experiment Station, Georgia School of Technology, Atlanta, Ga., 1938.

The writer would like to comment, however, on the statement that C_p formulas of full-range accuracy are "discouragingly cumbersome." The full-range formulas developed in a bulletin[6] of the Georgia State Engineering Experiment Station are accurate to the extent of a maximum error of less than 2 per cent and the use of these formulas in specific-heat or enthalpy calculations entails no more steps of slide-rule operation or arithmetic than are required with an equation of the form, $C_p = A + BT + CT^2$.

If the equations of the bulletin[6] do not give sufficient accuracy over the desired range, more accurate equations may be developed. But this is a tedious process at best and, in most cases, more than one equation will be required to give equal accuracy if the range is greater than about 2500 F. In Table 13 of this discussion, values of C_p and H, as calculated by representative full-range equations of the bulletin[6] are compared with the values tabulated by the author. These calculations were made with an ordinary log-log slide rule, and the agreement may be seen to be reasonably good.

When making calculations with gaseous mixtures, such as for internal-combustion-engine work, the writer has found it more convenient to use curves instead of tables or equations. If the mixture consists of three or fewer gases the curves for C_p, H, and U are computed more easily from tabulated values than directly with equations. It appears impractical to publish comprehensive tables of the many gaseous mixtures considered in various applications, but tables for the most commonly used pure gases, such as air and some combustion products might well be worth while.

W. M. D. BRYANT SUGGESTS SIMPLIFIED METHOD FOR MOLECULAR-HEAT DETERMINATIONS

W. M. D. Bryant[7] stated: The author has rendered a valuable service to the engineering profession in making available in an immediately useful form the results of recent precision calculations of gaseous molecular heats, obtained with the aid of spectroscopic data. The molecular-heat data he has selected are representative of the most reliable calculations now available. There is every reason to believe that these calculations are of an order of precision and accuracy not yet attained by the more direct experimental methods. By confining his tables to common nonhydrocarbon combustion gases he has been able to use calculations involving a minimum of uncertainty. The number of substances investigated in this thorough manner is as yet limited mainly to diatomic and in a few instances triatomic molecules. It is possible to simplify drastically the treatment and still obtain calculated molecular heats within a few per cent of the true values. These more approximate methods are immediately applicable to a much larger number of gases and vapors and to molecules of greater complexity. An approximate treatment was outlined by the writer[8] several years ago and is still feasible. Recent work by Bennewitz and Rossner[9] as well as by Fugassi and Rudy[10] includes a somewhat less precise semiempirical treatment, applicable to more complex organic molecules. The exact status of this recent work is not clear but its potential value is great.

While it is true that no knowledge of the theory of spectroscopic molecular heats is required of the users of the author's tables, an elementary understanding of this theory would require no great mental effort and would benefit engineers and chemists alike.

[7] Ammonia Department, Chemical Division, Experimental Station, E. I. du Pont de Nemours & Co., Wilmington, Del.

[8] "Empirical Molecular-Heat Equations From Spectroscopic Data," by W. M. D. Bryant, *Industrial and Engineering Chemistry*, vol. 25, 1933, pp. 820–823, and 1022.

[9] "Über die Molwärme von organischen Dämpfen," by K. Bennewitz and W. Rossner, *Zeitschrift für physikalische Chemie*, vol. 39B, 1938, pp. 126–144.

[10] "Specific Heats of Organic Vapors," by P. Fugassi and E. Rudy, *Industrial and Engineering Chemistry*, vol. 30, 1938, pp. 1028–1030.

A. C. GULLIKSON NOTES DEFICIENCIES IN THERMODYNAMIC DATA

A. C. Gullikson[11] wrote: It is a well-known fact that certain phases of thermodynamic research have been handicapped by the lack of reliably accurate formulas and data pertaining to the thermodynamic properties of gases. This deficiency has been particularly obvious when the problem in hand involved a relatively wide temperature range.

Since 1928, several noteworthy contributions of thermodynamic data have been published, all of which are due to the work of a few spectroscopic investigators. However, it should be noted that, although the spectroscopic method of specific-heat determination has reached a successful status within the last decade, this achievement is not due entirely to any recent discovery or development, but is the result of progressive work by many scientific investigators over the period of years since Planck, in 1901, presented his notable quantum theory.

The special significance of these recent spectroscopically determined data is exemplified by the high degree of accuracy achieved throughout a temperature range of several thousand degrees, an achievement of quite obvious impossibility by any of the methods heretofore devised.

As a substantial step toward the realization of a long-needed improvement in these data for engineering use, the author has presented a commendable contribution. However, prior to final acceptance of the tabular data, the writer feels that further consideration should be given to two important aspects:

1 Regarding the evaluations of H (enthalpy) and U (internal energy), the writer feels that the zero basis should be at a temperature lower than the author's selection of 540 R. The requisite data below 540 R are available; therefore, no valid reason for this omission seems apparent. By lowering the zero basis, and thus avoiding the nuisance of minus values, the tables would then be of such scope and range that all phases of engineering research and calculation might find them applicable.

2 A critical examination of a fair portion of the author's computed data reveals some errors which, it is felt, are larger than should be neglected. It is admitted that Tables 4 and 5 of the paper show a satisfactory agreement between the original and the author's data, but the writer finds larger errors throughout Tables 1, 2, and 3, and these occur at temperatures not listed in Tables 4 and 5. This contention is based upon a comparison with the results of a nearly identical project completed by the writer some time ago. In this work, the writer also divided the entire C_p curve for each gas into several sections, but used more elaborate equation forms, in addition to some very careful, large-scale graphical means. It is therefore felt that all evaluations should be carefully rechecked.

A. R. GORDON FAVORS THERMODYNAMIC CALCULATIONS FROM SPECTRA

A. R. Gordon[12] discussed the paper as follows: As one who has been interested in the calculation of thermodynamic quantities from spectra, the writer is somewhat prejudiced in favor of data obtained in this way. However, it is probably safe to say that physical chemists now use with confidence results obtained by this method. The whole theory has received a very thorough test in recent years, particularly in the calculation of equilibrium constants for reactions and of free energies

[11] Assistant Professor of Mechanical Engineering, Stanford University, Calif. Mem. A.S.M.E.

[12] Professor of Physical Chemistry, University of Toronto, Toronto, Ont., Can.

of formation. In fact, the latest development is to use measured specific heats to obtain information as to the internal-energy states of complex molecules for which direct spectroscopic analysis is not feasible as yet. The work of Kistiakowsky and his associates on the vexing question of internal rotation about carbon-carbon bonds is a case in point.

However, it is necessary to give a word of warning; the calculated spectroscopic quantities as recorded in the literature are almost always for the substance in the ideal gaseous state, and for high pressures the use of such values may cause appreciable errors. The difficulty is not serious since, if the equation of state be known, an appropriate isothermal integration from low pressure (where the gas is sensibly ideal) to the pressure in question will yield the requisite correction.

The author's tables for steam apparently do not include the Wilson correction[13] for rotational distortion; at the time the writer's tables were made, this correction was not available. In the case of the heat capacity, it is given to an excellent approximation by $8.11 \times 10^{-5}T$; thus the entry for 5400 R should be increased by 0.243 to 13.331.

The writer agrees with the author's contention that any data which are to be used extensively should be tabulated rather than be given by an empirical approximation formula; the interval in such tables should be fine enough to permit interpolation, using first or at most second differences. If the exact spectroscopic calculation on which the table is to be based has been made only for a few widely separated or irregularly spaced temperatures, there is one method of interpolation which (in the writer's experience) sometimes yields more reliable results than those obtained from a power-series development in T. It is based on the fact that the so-called "rigid rotator-harmonic-oscillator" approximation usually gives a reliable estimate of thermodynamic quantities.

Taking as an example the heat capacity of nitrogen, a typical diatomic gas, the approximation consists in effect in assuming that the translational and the rotational energy make their full classical contribution, and that the remaining internal energy of a molecule can be represented closely enough by a quantized harmonic oscillator, the fundamental frequency of which can be obtained from the band spectrum. The approximate value of the heat capacity is thus assumed to be $C'_p = R[3.5 + \varphi(\theta/T)]$, where $\varphi(x)$ is the Einstein function $x^2 e^x/(e^x - 1)^2$, $\theta = hc\omega/k = 1.432\omega$, ω is the fundamental frequency in cm^{-1}, T is the Kelvin temperature, and h, c, and k are Planck's constant, the speed of light and the Boltzmann constant, respectively. For nitrogen, $\omega = 2367\ cm^{-1}$, hence $\theta = 3389$ K. Table 14 with this discussion gives the exact value of C_p from the author's tables, the approximate value C'_p, and the resulting value of $\delta = C_p - C'_p$ for six widely separated temperatures.

TABLE 14 NITROGEN DATA

T deg K	500	1000	1500	2000	2500	3000
C_p	7.071	7.821	8.334	8.604	8.761	8.860
C'_p	7.058	7.779	8.275	8.527	8.663	8.743
δ	0.013	0.042	0.059	0.077	0.098	0.117

A glance at the lowest line of Table 14 shows that a simple graphical interpolation of δ will yield results at intermediate temperatures accurate to a few thousandths of a calorie per mol per degree, and thus, since there are adequate tables of $\varphi(x)$ which can be interpolated readily, values of C_p may be obtained with relatively little labor for as many intermediate temperatures as are desired for the final table.

The values of δ for nitrogen are typical of what may be expected as to order of magnitude for most diatomic molecules. Oxygen, however, is a notable exception; the lowest excited electronic state of the oxygen molecule lies relatively close to the normal ground state and, consequently, makes an exceptionally large contribution to the heat capacity. A reasonable approximation is given in this case by

$$C'_p = R[3.5 + \varphi(2225/T) + {}^2/_3\, \varphi(11287/T)]$$

where the last item gives a rough estimate of the contribution of the excited state; with this expression for C'_p, δ for 3000 K is only 0.213.

For steam, a typical triatomic unsymmetrical rotator, C'_p is given by

$$C'_p = R[4 + \varphi(2284/T) + \varphi(5155/T) + \varphi(5379/T)]$$

since here there are three fundamental frequencies, 1595, 3600, and 3740 cm^{-1}. The first line of Table 15 gives the author's values to which have been added the Wilson correction,[13] the second C'_p and the third the resulting δ; here again δ can be interpolated graphically without difficulty.

TABLE 15 STEAM DATA

T deg K	500	1000	1500	2000	2500	3000
C_p	8.420	9.880	11.273	12.248	12.898	13.331
C'_p	8.399	9.833	11.146	12.030	12.582	12.934
δ	0.021	0.047	0.127	0.218	0.316	0.397

E. D. GRIMISON EXPLAINS METHOD OF CHECKING DATA

E. D. Grimison[14] said: In Fig. 1 of the paper, the author compares the best previous values with the new data which he has compiled, and for several gases the changes are most important, particularly at high temperatures. It must, of course, be remembered that these are true or instantaneous values. Mean specific heats between a low "base" temperature and gas temperatures moderately high are not changed to as great degree.

The writer was satisfied some years ago of the accuracy of new values of specific heats based on interpretations of band spectra, by comparisons with data determined by improved applications of the older techniques of direct calorimetry and sound-velocity measurements. Comparisons of this sort, which show satisfactory agreement with values determined by other investigators using other methods, are most convincing demonstrations to the majority of engineers of the validity of data determined by new methods. This is particularly true as the determinations depend in considerable part on theoretically derived relationships. The author's values have been subjected to the same comparisons, as shown in the following, with generally satisfactory and convincing agreements resulting.

In Fig. 1 of this discussion, the author's data are compared with those of P. S. H. Henry[15] for oxygen and nitrogen; Henry's values resulting from calorimetric measurements. Henry reported molar specific heats at constant volume and the author's data have been converted to values at constant volume by deducting 1.985 from the constant-pressure values. His values are about 0.5 per cent lower than Henry's at 150 C and about 1.7 per cent at 300 C.

Values of mean specific heats for oxygen at constant volume, between 27 C and temperatures ranging up to 2200 C, are reported by Lewis and von Elbe,[16] who used direct calorimetry.

[13] "The Effect of Rotational Distortion on the Thermodynamic Properties of Water and Other Polyatomic Molecules," by E. B. Wilson, Jr., *Journal of Chemical Physics*, vol. 4, 1936, p. 526.

[14] Associate Professor of Mechanical Engineering, The Pennsylvania State College, State College, Pa. Mem. A.S.M.E.

[15] "The Specific Heats of Air, Oxygen, Nitrogen From 20 C to 370 C," by P. S. H. Henry, Proceedings of the Royal Society of London, series A, vol. 133, 1931, p. 492.

[16] "Heat Capacity of Oxygen at High Temperatures From Ozone Explosions," by B. Lewis and G. von Elbe, *Journal of the American Chemical Society*, vol. 57, 1935, p. 1400.

Comparisons are not shown here, but Lewis and von Elbe's values will be averaged very satisfactorily by the author's, over the range 1150 C to 2200 C. There are indications of small but increasing departure at higher temperature, of the order of about 1.5 per cent at 2200 C (4000 F).

Sherratt and Griffiths of the (British) National Physical Laboratory reported[17] constant-volume specific-heat values for

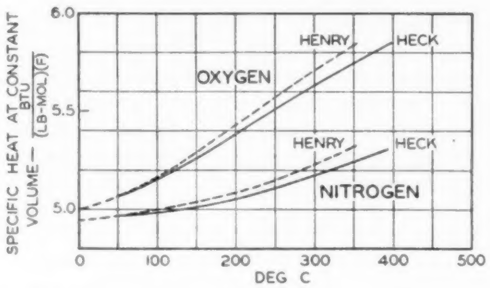


FIG. 1 SPECIFIC HEATS OF OXYGEN AND NITROGEN

(Comparisons of author's data with Henry's; based on calorimetric measurements.)

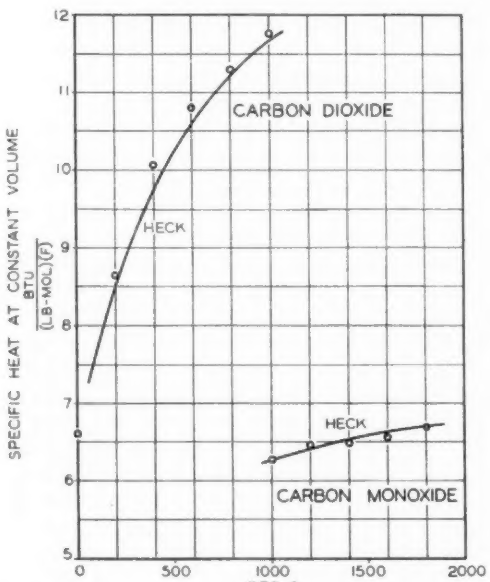


FIG. 2 SPECIFIC HEATS OF CARBON DIOXIDE AND CARBON MONOXIDE

(Comparisons of author's data with those of Sherratt and Griffiths; sound-velocity measurements.)

carbon dioxide and carbon monoxide. These are compared with the author's data in Fig. 2 of this discussion. The comparisons show agreements astonishingly good, considering differences in experimental methods—Sherratt and Griffiths having used sound-velocity measurements.

Most of the data on specific heats of gases now in use are based on measurements of sound velocity. Sherratt and Griffiths note that earlier measurements were made at a single frequency of sound, which method was discovered more recently to be fundamentally in error. The values shown in Fig. 2 of this discussion resulted from measurements at more than one frequency.

[17] "The Determination of the Specific Heat of Gases at High Temperatures by the Sound-Velocity Method," by G. G. Sherratt and E. Griffiths, Proceedings of the Royal Society of London, series A, "I–Carbon Monoxide," vol. 147, pp. 292–308; and "II–Carbon Dioxide," vol. 156, pp. 504–517.

The author's data are derived from original investigations of Johnston and several collaborators, Kassell, and Gordon, as cited in the paper. The earlier studies of Sweigert and Beardsley[6] (1938), cited by the author, and of Justi and Lüder[18] (1935), were based on the same original sources. The author's interpretations of the original data are supported by comparisons with the earlier studies. His values are practically identical with those recommended by Justi and Lüder, and also with those of Sweigert and Beardsley except for nitrogen. His values for nitrogen differ from Sweigert and Beardsley's from +12 per cent to —3 per cent in the range 80 F to about 2000 F. Above 2000 F (scale), the values are practically identical.

As judged from these comparisons and taking into account the greater susceptibility of other methods to experimental errors due to high temperatures, it appears that the new data are a distinct advance over those previously available.

It may be noted incidentally that this new procedure which bases specific heat values on band spectra combined with theoretical development, as outlined in the addenda to the paper, has already received the limited approval of mechanical engineers generally by the acceptance of the Keenan and Keyes tables.[19] Specific heats of water vapor used in Keenan and Keyes's values are from Gordon's correlation of spectroscopic data cited by the author.

H. L. JOHNSTON ATTRIBUTES GREAT ACCURACY TO SPECTRA METHOD OF DETERMINING THERMODYNAMIC PROPERTIES OF GASES

H. L. Johnston[20] stated: The use of spectra for obtaining the specific heats and other thermodynamic properties of gases is quite properly displacing other methods, because of the high accuracy attainable when adequate spectra are available. In the original sources, tabulations of the thermodynamic properties so obtained are on the Kelvin scale of temperature. Interpolations to convenient temperatures on the Rankine scale, as carried out and tabulated by the author, should be very useful for ready reference in the solution of engineering problems for which data are taken on the Fahrenheit scale.

A significant correction is necessary in the author's tables for steam to compensate for the energy absorbed in centrifugal stretching of the rotating water molecules.[13] The spectroscopic data on water vapor were not complete when Gordon[21] made the calculations on which this table is based. The needed rotational data have since been made complete[22] and the necessary correction for this behavior has been reliably computed by Stephenson and McMahon[23] and by ourselves. The correction is easily applied as it merely adds to the specific heat a contribution equal to 0.0000926 T (Kelvin scale) or 0.0000514 T (Rankine scale). The correction to heat content (Rankine scale) is 0.0000257 T^2. Table 16 of this discussion includes these corrections.

There has also been some improvement in the vibrational constants for the water molecule based on the more complete

[18] "Spezifische Wärme Entropie und Dissoziation technischer Gase und Dämpfe," by E. Justi and H. Lüder, *Forschung auf dem Gebiete Ingenieurwesens*, vol. 6, Sept.–Oct., 1935, pp. 209–216.

[19] "Thermodynamic Properties of Steam, Including Data for the Liquid and Solid Phases," by J. H. Keenan and F. G. Keyes, John Wiley and Son, Inc., New York, N. Y., 1936.

[20] Professor of Chemistry, The Ohio State University, Columbus, Ohio.

[21] "Calculation of Thermodynamic Quantities From Spectroscopic Data for Polyatomic Molecules," by A. R. Gordon, *Journal of Chemical Physics*, vol. 2, 1934, p. 65.

[22] "The Far Infrared Spectrum of Water Vapor," by H. M. Randall, D. M. Dennison, N. Ginsburg, and L. R. Weber, *Physical Review*, vol. 52, 1937, p. 160.

[23] "The Rotational Partition Function of the Water Molecule," by C. C. Stephenson and H. O. McMahon, *Journal of Chemical Physics*, vol. 7, 1939, p. 614.

TABLE 16 STEAM TABLE CORRECTED FOR CENTRIFUGAL STRETCHING CONTRIBUTION

T deg R	C_p	H	U	T deg R	C_p	H	U
600	8.08	483	364	3100	11.77	25345	20264
700	8.17	1296	979	3200	11.88	26528	21248
800	8.29	2119	1603	3300	11.99	27721	22242
900	8.43	2953	2238	3400	12.09	28926	23249
1000	8.57	3802	2879	3500	12.18	30140	24265
1100	8.73	4667	3556	3600	12.27	31365	25291
1200	8.88	5548	4238	3700	12.36	32597	26324
1300	9.04	6444	4935	3800	12.44	33839	27368
1400	9.21	7357	5650	3900	12.52	35387	28718
1500	9.38	8286	6381	4000	12.59	36344	29476
1600	9.55	9232	7128	4100	12.67	37607	30541
1700	9.72	10195	7892	4200	12.74	38876	31611
1800	9.89	11175	8674	4300	12.80	40152	32689
1900	10.06	12172	9473	4400	12.87	41434	33772
2000	10.23	13187	10289	4500	12.93	42723	34862
2100	10.40	14220	11124	4600	12.98	44018	35959
2200	10.56	10560	11974	4700	13.04	45320	37062
2300	10.71	16333	12840	4800	13.09	46628	38172
2400	10.87	17412	13720	4900	13.14	47941	39286
2500	11.01	18506	14616	5000	13.19	49258	40405
2600	11.15	19613	15524	5100	13.24	50580	41529
2700	11.29	20735	16447	5200	13.28	51906	42656
2800	11.42	21867	17381	5300	13.32	53236	43787
2900	11.54	23016	18332	5400	13.36	54570	44923
3000	11.66	24175	19292				

analysis of its spectrum. This will produce some further change in the tabulations for steam but the more exact values cannot be given at the moment. We are computing new tables for steam with these fuller spectroscopic data and will publish these when completed. For most practical purposes Table 16, with the corrections for centrifugal stretching, is sufficiently accurate.

The tables for O_2, N_2, H_2, and CO are based on complete and accurate spectroscopic data, while those for CO_2 are subject only to minor corrections, of the same character (but lesser magnitude), as those referred to for steam.

F. G. KEYES CALLS ATTENTION TO WATER-VAPOR STUDIES

F. G. Keyes[24] wrote: The author's discussion of heat capacities is timely for the procedures are now well established for deducing heat capacities from spectroscopic data. The case for diatomic molecules is fairly complete both from the point of view of theory and the existence of adequate band-spectrum data. The theory for triatomic molecules, linear type, and for some of the "bent" types such as the water molecule are also capable of accurate treatment although high spectrum resolution is needed and the data are not yet sufficiently extensive in many cases of practical interest. For more complex molecules, the normal modes of vibration are complicated and a great deal of spectrum data need to be taken.

Recently computations using extensive new data on the spectrum of water vapor have been completed.[23] The heat capacities computed therefrom verify all the best knowledge of the heat capacities from independent sources and the quantity $C_p{}^0$ for this substance is now known within 1 part in 1000 over the entire range of practical use.

L. C. RUBIN POINTS OUT LIMITATIONS OF METHOD

L. C. Rubin[25] said: The writer agrees that the thermodynamic properties of simple substances in the gaseous state can now be calculated more accurately from quantum-mechanical analysis of spectroscopic data than they can be measured experimentally. It may be noted that the method used in the paper was also employed in constructing a portion of the steam tables,[19] summarizing the research program sponsored by the A.S.M.E. on the Thermal Properties of Steam.

Two limitations of the method employed by the author may be pointed out:

1 The method gives only limiting values of the specific heat, enthalpy, and energy as the pressure of the gas approaches zero.

2 In the present state of knowledge the interpretation of spectroscopic data becomes increasingly difficult for the more complex molecules. For this reason, thermal data pertaining to complex substances, such as hydrocarbons, computed from spectroscopic data without independent experimental confirmation are less reliable than data for simple substances, such as have been treated in the paper.

H. M. SPENCER COMPARES SPECTRA RESULTS WITH DIRECT MEASUREMENTS

H. M. Spencer[26] stated: The original calculations from spectroscopic data of the thermodynamic data upon which they are based have given more accurate values of these quantities than it has been possible to obtain by direct measurement. The values up to room temperature and at moderate temperatures above have been checked by direct measurements of heat capacities, etc., and particularly by comparison of the entropies, say at 25 deg C, determined (1) from the spectroscopic data and (2) by the Third Law of thermodynamics and calorimetric measurements from near 0 K. At the higher temperatures, the most important tests have been made by comparison of calculated and experimental equilibrium constants.

The theoretical treatment of most diatomic molecules (including all those herein discussed) has been made in a completely satisfactory manner. The treatment of the simpler polyatomic molecules (including now even the simpler hydrocarbons), though less complete, is adequate for most uses. Thus, the data for $CO_{2(g)}$ and $H_2O_{(g)}$ are less satisfactory than those of Tables 1 and 2 in the paper. More recent studies by Wilson,[13] and by Stephenson and McMahon[23] indicate that an additional "stretching" contribution should be added to the heat capacity of water vapor as calculated by Gordon.[21] This may be expressed with certainty to 300 K and probably with accuracy to 1000 K by the addition of the term $4.66 \times 10^{-8}RT$.

It may be well to emphasize that these data are for the infinitely dilute or ideal gaseous state, which physical chemists indicate by superscript^0, i.e., $C_p{}^0$. Extension to higher pressures may be made from p-V-T data, as for example papers[27] by W. E. Deming and L. E. Shupe.

The writer has made random tests of data of the author's Tables 1, 2, and 3, as derived from the original papers, and has proved the general accuracy of the entries. Minor objection might be made to the use of the ω value (1.985 cal-mol^{-1} °K^{-1} or 1.985 Btu lb-mol^{-1} °R^{-1}) of R.

Greater clarity of meaning is needed in connection with the terms "absolute H_0" and "gaseous H_0" (at 300 K). What is actually meant may be represented by $H^0{}_{300}$—$H^0{}_{0(s)}$, and $H^0{}_{300}$—$H^0{}_{0(g)}$, respectively. The two quantities should not be equal. Comparison really yields the difference in heat content at the absolute zero of the hypothetical ideal-gas phase and the solid phase. Complete discussion, particularly of the first and last entries in the tabulation of these values would be quite extended.

[24] Director, Research Laboratory of Physical Chemistry, and Head of Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Mass.

[25] Petroleum Research Director, The M. W. Kellogg Company, Jersey City, N. J.

[26] Cobb Chemical Laboratory, University of Virginia, University, Va.

[27] "Some Physical Properties of Compressed Gases," by W. E. Deming and L. E. Shupe, *Physical Review*, Part 1—"Nitrogen," vol. 37, 1931, pp. 638–654; Part 2—"Carbon Monoxide," vol. 38, 1931, pp. 2245–2264; Part 3—"Hydrogen," vol. 40, 1932, pp. 848–859; Part 4—"The Entropies of Nitrogen, Carbon Monoxide, and Hydrogen," vol. 45, 1934, pp. 109–113.

The writer suggests that the empirical equations derived from the same data by the method of least squares by J. L. Justice and the writer[4] are simple to apply to the calculation of H^0 and S^0 and, while they do not yield the accuracy in these quantities of which careful graphical or graphical-numerical methods are capable, their accuracy is generally adequate.

D. D. STREID CALLS FOR CORRECTIONS IN APPLYING DATA TO ACTUAL GASES

D. D. Streid[28] commented as follows: In the early days of engineering, the specific heats of gases were thought to be independent of temperature, with values as determined by the kinetic theory. Later, direct experimental determinations were made of the specific heats at various temperatures, showing them to increase with temperature at high temperatures. This is ably reviewed by Partington and Shilling.[29] Now, from the latest advances of physics, yet different specific heats at high temperature have been obtained which are in general higher than the values previously accepted. A study of the original sources of these data shows that the physical chemists admit the possibility that some small additional quantum states as yet undiscovered may exist which will lead to a small increase of the specific heats shown in the tables of this paper at high temperatures. However, no future discovery can lead to a decrease of any of the values given in these tables. We may expect to see these values increased in the future, although estimates show that any further increases will be small compared to past increases. Because of the indisputable evidence supporting these specific-heat data, the writer believes they should be adopted in all engineering calculations. If more accurate values are established, they should be adopted immediately.

All of the data presented in the paper are for an ideal gas at zero pressure. This fact should have been more clearly stated in the paper. To apply these data to an actual gas it is necessary to make corrections for Van der Waal's imperfections because, by definition of an ideal gas, these forms of imperfection are excluded. These corrections depend upon the equation of state of the real gas and they are considered if the true specific heat is obtained by the integration of Clausius' equation

$$\left(\frac{\partial C_p}{\partial P}\right)_T = -AT\left(\frac{\partial^2 v}{\partial T^2}\right)_P$$

where the constant of integration is the specific heat at zero pressure as a function of temperature as given in the tables of this paper, and the relation between v, T, and P is the true equation of state. The enthalpy may be obtained from the true specific heat as discussed and from the true equation of state by integration of the thermodynamic equation

$$dH = C_p\,dT - A\left[T\left(\frac{\partial v}{\partial T}\right)_P - v\right]dP$$

The difference between the specific heat at constant pressure and the specific heat at constant volume may be obtained from the true specific heat and from the true equation of state by the thermodynamic equation

$$C_p - C_v = -AT\,\frac{\left(\frac{\partial P}{\partial T}\right)_v^2}{\left(\frac{\partial P}{\partial v}\right)_T}$$

[28] Supercharger Engineering Department, River Works, General Electric Company, West Lynn, Mass. Jun. A.S.M.E.

[29] "The Specific Heat of Gases," by J. R. Partington and W. G. Shilling, D. Van Nostrand Co., New York, N. Y., 1924.

TABLE 17 SPECIFIC HEAT OF DRY AIR FROM NEW SPECTROSCOPIC DATA

Temperature Deg R	Temperature Deg F	Specific heat, C_p Btu per lb per deg F
500	40	0.2400[a]
600	140	0.2406
700	240	0.2417
800	340	0.2436
900	440	0.2461
1000	540	0.2491
1100	640	0.2522
1200	740	0.2554
1300	840	0.2585

[a] The data for this value were obtained by extrapolation and from the original sources.

Fortunately, the contribution to the specific heat from these imperfections is small for the common gases discussed in the paper at normal temperatures and pressures (except for H_2O). For temperatures above 0 F and pressures below 200 psi abs, the maximum contribution to the specific heat will be an increase of about 1.5 per cent (except for H_2O). In engineering practice therefore, the corrections may be neglected and the values in these tables used for temperatures above 0 F and pressures below 200 psi abs. Outside of these limits, the true equation of state should be considered, although its contribution to the specific heat generally will be small.

The specific heats of air probably are the most important data which may be obtained from this paper. The specific heats of air at zero pressure have been calculated from the spectroscopic data and are shown in Table 17 with this discussion. The composition of average dry air was taken as nitrogen, 75.4 per cent; oxygen, 23.2 per cent; argon, 1.2 per cent; miscellaneous (CO_2), 0.2 per cent.

The maximum error due to Van der Waal's imperfections in the specific heats of air in Table 17 for temperatures above 0 F and pressures below 150 psi abs will be 1 per cent. The error at atmospheric pressure (14.7 psi abs) and the temperatures above 0 F will be less than 0.05 per cent. Therefore, these values in the table may be used in engineering calculations.

Table 17 shows that, for normal engineering calculations, the specific heat of dry air may be taken as 0.240 Btu per lb per deg F at temperatures between 0 F and 250 F with a maximum error of less than 1 per cent. The writer also reached this same conclusion recently after an extensive review of all the available test data for the specific heat of air. The specific heat of moist air in the temperature range from 0 F to 250 F may be obtained by using 0.46 Btu per lb per deg F for the specific heat of water vapor and taking proportional parts by weight of specific heat of dry air and of water vapor. The maximum error in this range will be less than 1 per cent, providing the moisture content is less than 10 per cent by weight of the mixture.

The specific heat of "normal air" in this range from 0 F to 250 F will be 0.243 Btu per lb per deg F if the moisture content of the normal air is taken as 95 grains per lb of dry air. This represents average humidity conditions in this country and this specific heat of normal air may be used in most engineering calculations involving normal air. For a discussion of normal air refer to an article[30] by Dr. S. A. Moss.

R. I. SWEIGERT RETAINS THE MEANING OF THERMODYNAMIC TERMINOLOGY

R. I. Sweigert[31] wrote: It is preferable to maintain the meaning of terms used in thermodynamics. Therefore, the writer believes that it would be better to omit the term "heat content"

[30] "Fundamental Constants for Engineering Computations With Air," by S. A. Moss, *General Electric Review*, vol. 34, August, 1931.

[31] Professor of Mechanical Engineering, Director Freshman Engineering, Georgia School of Technology, Atlanta, Ga. Mem. A.S.M.E.

and retain the term "enthalpy," keeping the word "heat" for use only with energy in transition by conduction, convection, or radiation.

In that connection, we still use the word "heat" in "heat capacity" or "specific heat." If we were to be entirely consistent we should rename and redefine the quantity which we have called specific heat. One of the principal uses of this quantity is in the determination of internal energy and enthalpy changes.

The determination of the specific heat values does not involve heat but rather internal energies. The values are actually specific internal-energy changes and specific enthalpy changes. That implies that C_v and C_p may be defined as $\left(\frac{\partial U}{\partial T}\right)_v$ and $\left(\frac{\partial h}{\partial T}\right)_p$, respectively, and that some names, such as "internal-energy capacity" or "specific change of internal energy" and "enthalpy capacity" or "specific change of enthalpy" be applied, omitting the term heat. Such terms as mentioned might prove somewhat more cumbersome and some other more convenient and equally appropriate names might be worked out.

For educational purposes, the writer does not feel that he would be particularly in favor of gas tables. Vapor tables are necessary because of the more complex equations and time-consuming calculations which would be necessary without them. The situation is not quite the same for gases.

For repeating calculations which might occur in industry, special tables on gases might be an advantage. If the gas tables were sufficiently comprehensive, they would save time as compared with the use of equations. In the case of mixtures, the equation is likely to be more convenient than tables, since it is not difficult to determine the equation for a mixture; and when it is once determined, the mixture can be handled as readily as a single gas. Comprehensive tables for such gases as air might well be prepared if there is a demand for such tables.

G. B. TAYLOR CITES PREVIOUS WORK ON NUMERICAL TABLES

G. B. Taylor[32] stated: The writer is in agreement with the author that the thermal properties of gases should be expressed by numerical tables of heat content, and this appears to be the principal object of the paper. In 1934, the writer[33] also presented numerical values which agree quite closely with those in the paper when translated from deg C to deg R.

The writer agrees with the author's viewpoint that heat values calculated theoretically by the methods of modern physical chemistry are to be preferred over any experimental values, but doubts the advisability of carrying tables intended for engineering use to temperatures as high as 3000 K, in spite of the fact that the physical chemists do carry their calculations to 5000 K. Concentrations of whole molecules amount to little at such high temperatures.

M. JAKOB COMPARES VALUES OF JUSTI, LÜDER, AND HECK

M. Jakob.[34] Most of the calculations of specific heat from spectroscopic data were performed during the last five years, as the author mentions at the beginning of his valuable paper. These calculations were based either on Einstein's equation of the heat of oscillation, published in 1907, which assumes harmonic oscillation, or on Planck's "sum of state," published in 1915, which is free from this approximation. Possibly the first entirely reliable numerical computation[35] was made in 1926 by H. C. Hicks and A. C. G. Mitchell. These investigators, following a suggestion of Tolman, used and improved the second method. The differences in the results of the two methods can be seen from Table 18.

TABLE 18 SPECIFIC HEATS, C_p, DETERMINED FROM SPECTROSCOPIC DATA BY DIFFERENT METHODS

	1000 C			2000 C		
Gas	Justi[36]	Justi and Lüder[18]	Heck	Justi[36]	Justi and Lüder[18]	Heck
N_2	8.10	8.14	8.143	8.61	8.70	8.700
O_2	8.50	8.60	8.587	8.79	9.19	9.175
CO	8.20	8.24	8.244	8.66	8.75	8.753
H_2	7.36	7.49	7.482	8.10	8.38	8.385
CO_2	13.60	13.60	13.639	14.42	14.42	14.674
H_2O	10.56	10.58	10.582	12.34	12.45	12.449

Justi tabulated the values according to the first method, Justi and Lüder used the second method except for CO_2. This is the reason for the discrepancy of the values for CO_2 at 2000 C.

Justi and Lüder further tabulated values for N_2O, SO_2, Air, CH_4, C_2H_4, and C_2H_2, the latter three up to 1000 C only. The values for the two last gases are based on Einstein's method. For this reason they may be less accurate. The influence of dissociation, however, seems to be much greater than the difference of the two mentioned methods. At high temperature this influence must be considered, as at finite pressure the mutual forces between the molecules must be taken in account. Methods for both corrections are available.

AUTHOR'S CLOSURE

As evidence of wide interest, it is gratifying that this simple paper has drawn so large a body of discussion. Especially welcome are the contributions from Professors Johnston and Gordon, since they are the direct authorities back of five out of the six gas tabulations in Tables 1 to 3.

In two ways the paper falls into two parts. As to time, the first section was published in January, the second was added in May at the A.S.M.E. Spring meeting at Worcester, Mass., and only now appears in print. The other division, running through both sections, lies between the main purpose of presenting definite information and a supporting description of the background in scientific theory and research.

Evidently and naturally, the discussion relates mostly to the first section; and in large degree it concerns the background material. In this wide field only two remarks are now to be made by me. It is regrettable that the Wilson correction for H_2O, as noted by Professor Gordon, was not taken into account. As a far more important statement, it is my firm opinion that older knowledge and formulations are definitely superseded by the spectroscopic determinations. Under this thesis a few concise statements are to be made about the gas tables here offered.

Frankly, my acceptance of the new knowledge is in a spirit of faith and confidence rather than in one of critical examination and appraisement; that aspect of the subject may be handled by more competent critics.

Recalculation was motivated by the fact that the published tables are at long intervals in the higher range, too wide for effective interpolation; also, they deal rather sketchily with the heat quantities H and U, as compared with certain other properties.

My primary calculations were on the centigrade base, and the tables here given are interpolations at Fahrenheit intervals.

Choice of origin at 300 K was motivated by predominant interest in combustion problems. Incidentally it avoids the complications appearing to the left of the 300-deg line in Fig. 1.

[32] Chemical Department Experimental Station, E. I. du Pont de Nemours & Company, Wilmington, Del.

[33] "Heat Content of Gases From 0 to 1900 C," by G. B. Taylor, *Industrial and Engineering Chemistry*, vol. 26, 1934, p. 470.

[34] Research Professor of Mechanical Engineering, Illinois Institute of Technology, Chicago, Ill. Mem. A.S.M.E.

[35] H. C. Hicks and A. C. G. Mitchell, Journal Amer. Chem. Soc., vol. 48, 1926, p. 1520.

[36] E. Justi, *Forschung auf dem Gebiete des Ingenieurwesens*, vol. 5, 1934, p. 130.

The degree of conformity of the C_p data to smooth curves is exhibited in Tables 4 and 5. Where discrepancies appear it means that my values are smoothed to that extent. Conformity of the original data to smoothness of variation is confirmatory of correctness.

The method of exact calculation by simple equations plus large-scale graphical corrections or adjustments is entirely valid; and it is much easier than to derive and use elaborate equations.

Check of my calculations was found in close agreement with the published physicists' results, at their own intervals. The other check on any table is smooth variation of differences. A plot of second differences from the new tables may show an occasional low hump or shallow flat; but the primary columns are self-consistent well within a band of the width of 1 in 1000.

As to the gas mixture, the use of Tables 1 to 3 is greatly facilitated by guide Table 11, which covers the range of combustion products.

On the question of formulas versus tables, it is my very strong opinion and conviction that the formula method should and will disappear from routine work with gases just as it has disappeared from work with steam. Specific-heat formulas can easily enough be integrated to equations for the heat quantities and entropies; but if workably simple they are only approximate; and if physically exact they become intricate and cumbersome in use. Nobody now thinks it necessary to use a mean specific heat or to integrate a specific-heat formula in order to get the enthalpy of superheated steam, although there was a time when that kind of practice prevailed. Now, with dependably correct data for gases, why not relegate computation to specialists and put results into tables for convenient routine use?

Here is a concrete proposal:

For combustion problems, assume that all the gases involved conform to the general gas equation $pV = mRT$, with $mR = 1.985$ for the mol. This means that pressure effect may be disregarded. In the low temperature range pressure is also low; at high temperatures pressure effects really do become insignificant, at least within the limits of engine pressures. With a low gas, toward saturation, the equivalent of a steam table becomes necessary anyhow.

Take the tables here presented as the beginning of a collection of tables of the thermal properties of gases, adding such others as may seem most necessary or appropriate, and put them into the form of a small pamphlet, in effect a handbook section. This might be a project for the Society, sponsored by the Divisions directly interested.

In the original paper as published in the January, 1940, issue of MECHANICAL ENGINEERING, there were two errors in Table 3. In the third column from the left the nineteenth line of figures from the bottom should read 39423 and not 39243. In the fourth column the last line of figures should read 56383 and not 65383.

R. C. H. HECK.[37]

[37] Research Professor in Mechanical Engineering, Rutgers University, New Brunswick, N. J. Mem. A.S.M.E.

International Trade Relations After the War

(Continued from page 125)

tinuous struggle for their possession or, on the contrary, assurance of equal access to them on a multilateral trading system buttressed by collective security" (p. 370). The latter alternative is possible should Great Britain emerge victorious or should the war end in a compromise or a stalemate. But if the world is to achieve this goal the United States must be prepared to use its economic, financial, and political power more effectively than it has in the past. The author concludes that the system which will "govern the future of international relations will be determined very largely, on the one hand, by the willingness of the United States to make good its professed policy of peaceful trading development and, on the other, by the readiness of the British Commonwealth to give up immediate strategic and economic advantages for the larger security and economic opportunity of participation in a world trading system."

The author introduces many subjects and raises many questions which cannot be dealt with in a short review. One of the most interesting parts of the book is the discussion of the relationship of national to international planning. He believes that centralized quantitative control of international trade by government action is incompatible with the development of international economic cooperation. He distinguishes between the "regulation of the market" and "actual government operation of economic activity," and states that "there seems to be no insuperable obstacle to international coordination of national policies if they are confined to the regulating function, but there is little possibility of coordinating detailed plans of rationing and credit control" (p. 352). Later in the same chapter he writes that, if there is to be multilateral trade conducted by the mechanism of the market, stability of exchange rates is important, and there can be no such stability if each nation uses its control of international trade to discriminate between different types of economic activity.

There must be cooperation between the monetary authorities of the different trading areas both as to the exchange rates that should be established and as to the policies to be followed in maintaining them. The rates, of course, must be established with reference to relationship between national price levels and these relationships must be such as will enable trade to flow freely without disturbing the balances of external payments. Thus, even if the United States should extend large credits to finance the reconstruction of Europe after the war, this relief could only be temporary. "But in the long run, and not too long a run, the United States must accept a large passive balance of imports. This can be brought about by a reduction of the American tariff, by prices rising in the United States faster than elsewhere, by other currencies depreciating against the dollar, or by some combination of all three of these developments" (p. 378). When we consider how difficult it will be to adhere to a policy of this sort, we get some idea of the obstacles in the way of that thorough-going international collaboration which Mr. Condliffe insists is necessary to reconstruction of world trade.

In the early part of the book the author emphasizes the conflict of nationalism and industrialism, pointing out that the disorganization of international economic relations is attributable chiefly to the "politization of the economy." The primary cause of the exaggerated nationalism of recent years is education conceived exclusively in terms of political citizenship . . . ." (p. 116). "State intervention in such fields as exchange control and clearing arrangements has been logically and methodically calculated to enhance the military strength of totalitarian states." And so the book ends on the same note. The political problem must be solved before a solution can be found for the economic problem. "No system of economic or financial cooperation can be effective for long unless it is firmly based on political security, which means collective security" (p. 394).

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals and Events

MATERIAL for these pages is assembled from numerous sources and aims to cover a broad range of subject matter. While few quotation marks are used, passages that are directly quoted are obvious from the context and credit to original sources is given.

Section M (Engineering) A.A.A.S.

ECONOMIC and engineering interests of the Americas was the theme of the annual meeting of Section M (Engineering) of the American Association for the Advancement of Science held at the Engineers' Club of Philadelphia on December 31, 1940. The excellence of the program, which was developed in cooperation with George Howland Cox, director of the Inter-American Center of The George Washington University and the officers of Section M, warranted an audience of several hundred engineers instead of the corporal's guard that was present at the morning and afternoon sessions. At the luncheon meeting, held in connection with, and through the courtesy of, the Club, a crowded dining room greeted Dr. William Culbertson, former Ambassador to Chile, who told many anecdotes of his personal experiences in Latin America.

With R. L. Sackett, vice-president of Section M, presiding, the morning session opened with a paper by Jerome C. Hunsaker, vice-president A.S.M.E., head of the department of mechanical engineering, Massachusetts Institute of Technology, on technical progress in aviation. The paper is published elsewhere in this issue (pages 95–97).

Cultural Relationships

Following Doctor Hunsaker's paper, Dr. Cloyd Heck Marvin, president of The George Washington University, spoke on cultural relationships between the Americas.

He had heard much, he said, about "hemisphere defense," but in his opinion defense itself would never bring the Americas together. Until understanding broke down "out-group" feeling and engendered "in-group" feeling, we would never have good will. As long as our money held out, the "good-neighbor" policy was fine, but it was impossible to buy Latin American good will.

Experiences at the Scientific Congress in Mexico City in 1935 had demonstrated to him that scientific and engineering congresses provided a common meeting ground for intelligent citizens of all the Americas. Engineers, he said, should be able to advance the cause of inter-American friendship. There had been a lag in economic development in Latin America and this had held back engineering development, but when conditions should become propitious, progress would be more rapid than it had been in the United States.

Doctor Marvin spoke in praise of the engineering schools of Latin America and said that their number and importance were indications of the falsity of the belief that the engineering profession and engineering industries were looked down upon. He urged the more frequent exchange of professors among the schools of the hemispheres and mentioned some of the difficulties in the way of the program.

There were, he said, about 300 Latin-American students in schools in the United States. These students preferred to live in the typical school atmosphere to be found here rather than in special houses. It was unfortunate that because of government restrictions and labor agreements it was practically impossible for Latin-American engineering students to work in industries in this country.

Difficulties in language, in unfavorable exchange rates, in the differences in national background and social atmosphere, and in laws restricting internship had to be met by Latin-American students coming to this country to study engineering. As to the attendance of students from this country at schools in Latin America, only in the arts and sciences could such be found at present.

He suggested that annual missions be established with the object of "getting behind the scenes" of engineering developments and opportunities in Latin America, and said that there was a challenge to the engineering societies of this country to accept leadership in such a demonstration of inter-American interest and good will.

Press Defended

An able defense of the press of the country was expressed by Raymond Clapper, political commentator of the Scripps-Howard newspapers, directly following Doctor Marvin's address.

Mr. Clapper said that a special effort was being made by the press of the United States to use skilled reporting in the engineering field. New Deal ideas of the press were not complimentary, and it was true that just criticisms might be made of it. It was the object of most newspapers to inform the public on news events, to bring buyer and seller together by means of advertising, to provide entertainment through comics and special features, and to influence public opinion by editorial comment and special "columns."

Each of these four major functions was explained in considerable detail by Mr. Clapper. He said that never before had so much attention been given to gathering and presenting the news. That the news was colored might be true in the case of political campaign news. However, an earnest attempt was made to separate news and editorial opinion. Nothing could be gained by news coloring and public criticism was an effective weapon in a democracy. He analyzed certain suggested improvements of the press, none of which he found good. These were: Laws against misrepresentation, a government newspaper to publish "facts;" and a board to regulate "antisocial propaganda." In any event, it was his opinion that there should be no government tampering with the news. He gave strong arguments in favor of the advertising and entertainment features of newspapers and spoke in some detail on the effectiveness of newspapers in attempting to influence public opinion which, while vastly overrated, provided the main source of controversy.

In closing he restated his contention that the only safe and practical remedy for the alleged misuses of the power of the press was the pressure of public opinion. Editors, he said, were too likely to belong to the "country-club" group and hence were

not close enough to the public, and the press in general was slow to get a proper view of changes and developments.

"Good-Neighbor" Policy

At the luncheon, which was well attended and presided over by H. S. Murphy, president of the Engineers' Club of Philadelphia, Dr. Wm. Culbertson, former Ambassador to Chile, said that the "good-neighbor" policy with respect to Latin America had a long perspective in time and space. It had been initiated years ago with the Monroe Doctrine. Present conditions were giving renewed importance to the Monroe Doctrine, but as a result of it the Latin-American countries had contracted the habit of relying on the British and United States navies.

Doctor Culbertson's address was greatly enlivened by the narration of numerous personal anecdotes in connection with his long contacts with Latin-American countries and their public men. He made a point of his opinion that the "good-neighbor" policy had, in general, been a unilateral one, and that our relations with Latin America had been on the basis of "give and forgive." High esteem between two nations, as between men, he said, consisted in performing one's public duties and insisting upon one's rights. Our foreign policy should be on this basis. As it was, our attitude toward property protection in foreign nations had created a "financial vacuum" which had retarded development of Latin-American countries. Political loans might be justified, he said, but they offered no solution to inter-American problems.

Interchange of Students

In the absence of Richard Pattee, of the Division of Cultural Relations, United States Department of State, Harry H. Pierson, Mr. Pattee's associate, opened the afternoon session with an address on the interchange of students between the Americas. Such interchange, should, in his opinion, involve students who had already formed careers in their home countries and who were looking for additional education on the graduate-school level in the hope of broadening experience. There were three dangers in the exchange of undergraduates: The inability of the undergraduate to shift for himself in a foreign country; the immaturity of the undergraduate mind and his tendency to "go native;" and his inadequate intellectual preparation. The object should be to exchange the best cultural products.

Mr. Pierson spoke of numerous difficulties that confront the exchange student. There was first the language problem. Then it was the observed fact that the university system of Latin America did not provide an adequate educational basis because it was too superficial for admission to technical courses. The social relations of young people were quite different on the two continents and as a result adjustment was difficult. Expense was also a problem and one which was aggravated by the unfavorable rates of exchange.

There was, further, the question of national attitudes—our ignorant assumption of the "jingle-jungle" attitude toward Latin America. We must, on the other hand, remember that some Latin-American universities were older than any in North America, and that there was an intellectual aristocracy in Latin America. And finally, there was the adjustment necessary in the academic year, which was different in the two continents.

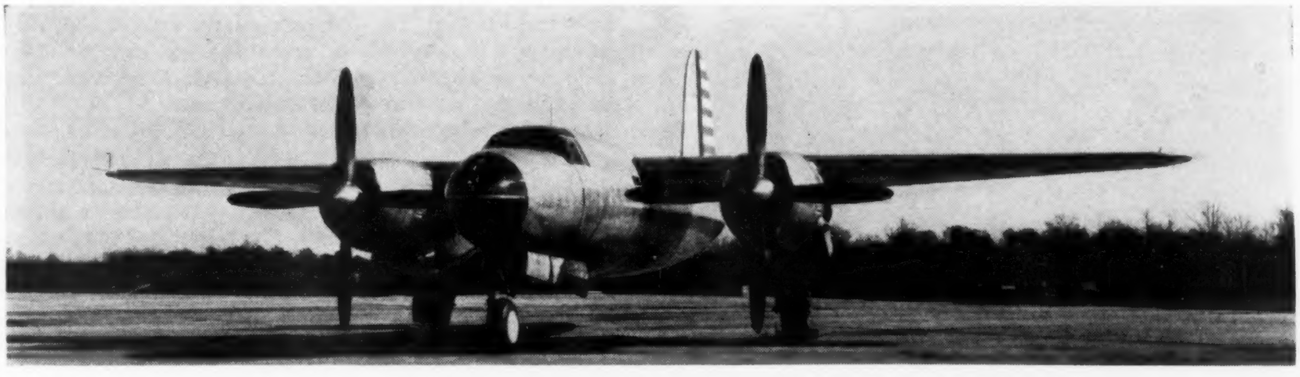
Mr. Pierson outlined what was being done officially, through the United States government, and unofficially through universities and foundations to foster interchange of students. In the academic year 1938–1939 the total number of Latin-American students in the United States was 1064, and in the year 1939–1940 this had been 1262. He told about the travel grants of the government that were available to a limited number of promising students and of schemes for providing maintenance while in residence.

Coming to the question, Where do the engineers come in? Mr. Pierson said that they could create graduate scholarships (the A.S.M.E. Woman's Auxiliary has such a scholarship named in memory of Calvin W. Rice, former secretary); they could set up special short courses for graduate engineers; they could send young engineers from this country to study research projects in Latin America; and they could provide teachers of engineering for Latin-American universities, 53 out of the total 67 of which offered some work in engineering.

In closing Mr. Pierson said that the three phases of hemisphere defense were political, economic, and cultural. It was necessary for the Americas to view their mutual problems intelligently. The day of the "good-will tour" was waning. Engineers were in a fortunate and challenging position to develop lasting inter-American friendships.

Engineering in Latin America

The subject of engineering developments in South America, with emphasis on their commercial and economic aspects, was discussed by Fred Lavis, consulting engineer, and adviser on engineering works for Venezuela. Mr. Lavis' address, which he summarized, was packed with sound sense and keen observation.



FAST MARTIN BOMBER READY FOR FINAL TEST

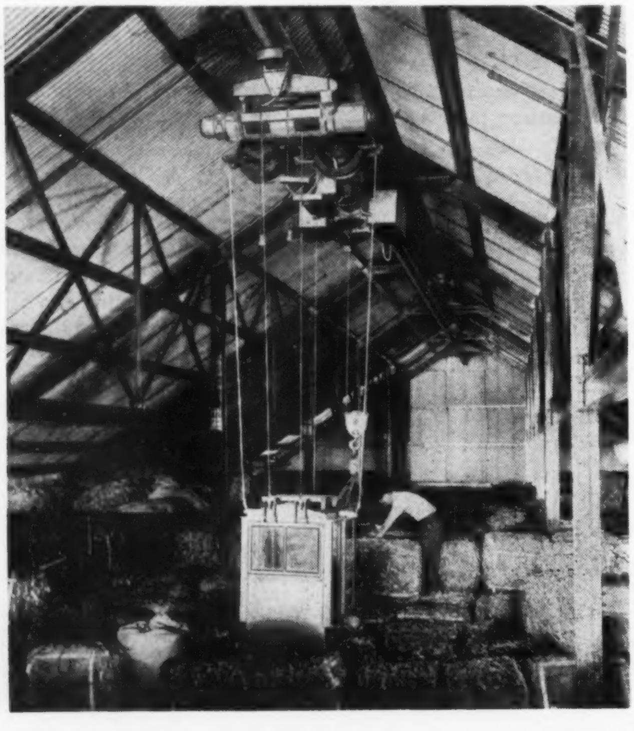
(Expected to prove itself the world's fastest bombing airplane, this Martin B-26 streamlined medium bomber of semi-high-wing design is equipped with a tricycle landing gear, two 18-cylinder, 1850-hp Pratt and Whitney engines, and two four-bladed propellers, has a gross weight of 26,625 lb, and will carry a normal crew of five men.)

War in Europe had accelerated the tempo of our relations with Latin America, Mr. Lavis said. We had been forced to consider defense of the Western Hemisphere, and we had attempted to help in the economic crisis in Latin America. These efforts, he said, would not be successful unless we were to understand our failures in the past.

Latin-American trade had been east and west, rather than north and south, and we could not permanently change its course. It was our duty to create new business. Although we had been too busy to become interested in Latin America, the British had been able to develop commercial and industrial enterprises there, and in this they had had the full cooperation of the British government in financial and business matters. This had not been true in respect to the United States, whose efforts had been sporadic and undertaken by individuals without benefit of a national policy. He was critical of the failure of the United States government to aid our citizens who were creditors to Latin America, and he said that the Securities and Exchange Commission had created an impression in Latin America that defaults were justifiable. It was, in his opinion, the duty of the government to defend the rights of its citizens abroad. This the United States government had failed to do.

It had been European practice to combine loans to Latin-American countries with opportunities for their citizens to produce wealth. In this, Europe had always been the "good neighbor." Our own government had recently gone into the loan business in Latin America, but in Mr. Lavis' opinion, we would not be the really good neighbor until our financiers did the financing, our businessmen carried on the business, and the government performed the duties of a government.

In a brief review of the commercial situation in Latin America Mr. Lavis pointed out that the countries there produced in general what we ourselves produced. Latin-American countries bought and sold in Europe in competition with us. It was wrong, as it was unwise, for us to think that we could capture this European trade, because Europe needed what Latin America had to offer, while we needed only a part of it. Thus the United States would lose out unless it could develop reciprocal interests.



TRAMRAIL CARRIER, WITH RAISE-LOWER CAB, HANDLES LOADS OF CORK

(Cab and hook are independently operated. Three men work on day shift, one in the cab, one attaching, and one detaching, loads and cab remains in upper position firmly fastened to tramrail carrier. On night shift, cab operator works alone, using raise-lower feature of cab.)

As to what we could do in such a situation Mr. Lavis pointed out that we could develop trade that did not exist today and thus attempt to do whatever would create exchange. To do this we needed trained personnel with a knowledge of Latin American affairs and an ability to speak the languages used there. He proposed the establishment of an endowment for the purpose of training young men to work in Latin America. These young men should be recruited from modest homes in small country towns. They should be accustomed to working for a living and should agree to work for three or four years for a modest salary. They should be given an education lasting six or seven years, including experience abroad. They should be taught to speak and write the languages of Latin America, and something of geography, history, engineering, trade, agriculture, and commercial practice.

Mr. Lavis then proposed a long list of activities in which we might engage and which would result in the production of wealth in Latin America, and commented on some of the conditions under which such activities would have to be undertaken.

In closing Mr. Lavis said that in our inter-American relationships, good faith, decency, and honesty were needed on both sides. Charity, he said, would not make good neighbors.

Materials

The two concluding papers of the meeting were presented by C. L. Warwick, secretary of the American Society for Testing Materials, whose subject was inter-American relations in the field of engineering materials; and Dr. P. G. Agnew, secretary of the American Standards Association, who spoke on exchange of standards between the Americas.

Mr. Warwick said that the A.S.T.M. was concerned especially with the promotion of knowledge of materials and the standardization of materials specifications and tests. It had about 80 members in Latin America, and the exchange of publications, including those of some 35 societies, engineers' clubs, and other Latin-American groups was mutually beneficial. The active work of the Argentine Standards Institute (IRAM) and the development of standardizing bodies in Brazil (now under way) and in Uruguay (contemplated) would certainly tend to intensify inter-American contacts, because the many problems involved in the testing and specifying of materials were of broad interest, but particularly from the consumer standpoint. Because of the probable rapid increase in consumption of materials in South and Central America, standardization and research should be stimulated.

As to further steps that should be taken and current activities that should be stimulated to bring about closer and mutually beneficial inter-American relations in the field of materials, he said that certainly the work of the Department of State, Bureau of Foreign and Domestic Commerce, and the American International Chamber of Commerce should be expanded; and that American industry could do more to acquaint their South American markets with much of the beneficial work already done in this country on such matters as research on properties of materials and testing, the development of quality standards, and the like.

The scope of the American Scientific Congress might well be expanded to cover certain topics on materials which are of inter-American concern.

We had lagged behind certain other countries which have been interested in South and Central American trade, in the promotion of American specifications and tests for materials for use in export trade, although some 60 A.S.T.M. standards had been published in French and Spanish in the 1920's and some 15 in the Portuguese tongue, this having been done through the Bureau of Foreign and Domestic Commerce. Just recently 13 A.S.T.M. standards on refractories had been translated into Spanish and will be published. Since these specifications and tests were essentially national standards, it seemed logical that their use should be extended where feasible. There was definite interest in them in South America.

The National Bureau of Standards and the Bureau of Foreign and Domestic Commerce were carrying out a program for establishing commercial standards for commodities exported, and publishing these standards in appropriate foreign languages. Since the translation of technical literature required special skill, this matter was receiving attention from several sources, notably the American Standards Association, which was considering the feasibility of providing a systematic arrangement for the translation of standards into foreign languages.

While it could not be categorically said that there should be inter-American Standards for materials until the economic and political situations respecting the Western Hemisphere had been somewhat clarified, to the extent that such standards provided a common ground of understanding and a common technical language, there were obvious advantages to be gained. Many questions beyond those of a purely technical nature would be involved in the establishment of such standards and one could do no more now than recognize the possibility of the question arising as our technical relationships with the Latin-American countries grew more closely together.

The need for working for the formation of an Inter-American Association for Testing Materials might develop and we should at least be thinking about it as a possibility. But again, questions of national policy both here and in the Latin-American countries might be involved, and our best course at the moment would seem to be to use existing organizations, such as the American Scientific Congress, as a means for promoting closer inter-American relationships in the materials field.

In conclusion, while various possibilities mentioned here warranted study, emphasis had to be placed on the importance of using to the full all the means that now existed to promote more complete interchange throughout the Americas of knowledge concerning the properties of, and tests and specifications for, the materials of engineering.

Standards

Dr. Agnew outlined the most important uses of standardization in connection with technology, industry, and business. These were: Standards of size and shape which provided for interchangeability of parts and supplies; specifications and grading rules which defined materials and products; definitions of technical terms used in specifications, contracts, and general business transactions; provisions for safety of workers in industry and for the protection of the public; and standards for purchasing, shipping, and operating routines which made possible effective administration of far-flung business enterprises.

The main function of standards, he said, was to facilitate the flow of products through transition points. Standards were both facilitators and integrators, and were important means of facilitating cultural interchange.

As early as 1924, he pointed out, a Pan-American Conference on Standardization had been held at Lima, Peru, in connection with a Pan-American Scientific Congress under the auspices of the Pan-American Union. An elaborate program had been planned and nearly all the American republics had been represented. Two years later a second conference had been held in Washington, at which the arrangements had been less elaborate and the program short and simple. Both congresses appeared to have been premature.

VIBRATION-FREQUENCY METER WEIGHING ONLY EIGHT OUNCES
(Vibrating reed, consisting of a thin steel spring clamped between set of steel rollers, is moved in and out by means of knurled knob. Sliding pointer on back of reed indicates vibration frequency which is read off calibrated scale on frame of instrument.)

According to the scale on which it was carried out, standardization might be classified roughly in four stages: By individual concerns; by associations and government bureaus; on a national scale; and on an international scale. As in all other countries, so also in Latin-America, engineering societies and groups had taken the lead in industrial standardization, while government agencies had played a leading part in agricultural standards. National standardizing bodies were operating in Argentina, Brazil, and Canada, as well as in the United States.

International standardization constituted the most difficult of the four stages, he said. There was an International Standards Association to which national standardizing bodies in 22 countries belonged at the beginning of the war. Among these were the American Standards Association and the Argentina national body. In the electrical field the International Electrotechnical Commission had national committees in several of the Americas. In the last few years the Inter-American Safety Council had come into being with national councils in Cuba, Costa Rica, Ecuador, Guatemala, Mexico, Venezuela, and the United States.

The war and dislocations of trade channels resulting from it had greatly quickened the use of standards in trade between the United States and Latin America. There was a growing demand for translations of American standards into Spanish and Portuguese. However, unilateral translation and distribution of standards was but one step toward an adequate inter-

change of standards between the Americas. There would have to be many more interchanges to bring about the necessary mutual understanding of technical matters, of industrial and commercial points of view, and of human relationships if these standards were to play a fully effective role in the interchange of products between the Americas and in improving the mutual understanding of their peoples. Cooperation would have to go much deeper. There would have to be an exchange of ideas and experience through correspondence and conferences, and continuous development of standards through their use in industry and trade.

A proposal had just been received, he said, for the setting up of systematic inter-American cooperation on standardization in the electrical industry. Some persons had even suggested that there should be a series of inter-American standards. Such an undertaking could lead far as it implied formal correlation between national standards of different countries. If we were to have national standards, regional standards, and international standards, which might conceivably differ, some of the advantages of standardization would be lost through the multiplicity of standards. Under the circumstances, therefore, it seemed to him that the question whether there should be inter-American standards might well be left for future determination, but in the meantime, we should proceed with far more intensive and extensive inter-American cooperation in standardization work.

If a fraction of one per cent of the sum now being spent on some spectacular attempts at a wholesale solution of problems were to be spent in building up a program of intensive and extensive inter-American cooperation on standards, he said in closing, the results might be more fruitful.

FOR THE ASSEMBLY OF WARNER AND SWASEY LATHES

(Small parts are tagged with the stock number at the stock room and packed in cellophane bags, which keep them intact yet fully visible.)

Locomotive Valves[1]

SEMI-ANNUAL MEETING, A.S.M.E., MILWAUKEE, 1940

STEAM-DISTRIBUTION valves and valve gears for modern high-speed steam locomotives are creating a great deal of interest, particularly because of the fact that large boilers of these locomotives, combined with increased superheat and high feedwater temperatures, provide an enormous increase in the volume of steam which can be delivered to the cylinders for a given weight on the driving wheels. The necessity of handling this steam to best advantage at high speeds presents an increasingly difficult problem in design of valves and valve gears. Of course, there are other design features to consider, such as size, shape, and length, and smoothness of steam passages and the volumetric capacity of the steam chest or reservoir adjacent to the port admitting steam.

There is no urgent need for a valve arrangement which will make it possible to operate steam locomotives at speeds in excess of 100 mph, because both the Walschaert and Baker gears are accomplishing this. What appears essential is to provide an arrangement which will be able to make full use of the higher steam pressures and temperatures now employed. Present practice is illustrated in Table 1 which shows the data covering the valve arrangements and settings on 20 modern passenger locomotives now operating in high-speed service in this country. It will be noted that 15 of the 20 engines have the Walschaert gear and the remainder, the Baker gear. This same distribution is maintained generally in new locomotive designs.

Either gear will produce about the same valve events when the same lap and lead are used. The Walschaert gear is, however, limited to a practical maximum travel of 8 in., although in some cases a travel of $8^1/_2$ in. has been possible. The Baker gear, on the other hand, has been used in many locomotives with a travel of 9 in. The principal shortcomings of the present gears obviously are the fixed relationship between the valve events and the difficulty of obtaining suitable steam-port openings at short cutoffs, without going to exceptionally long valve travel and large lead.

The characteristics of these gears are such that short cutoffs carry with them early release, early compression, and early preadmission. Long valve travel and large steam lap correct these difficulties to some extent but even the long-travel gears have some difficulty when cutoffs much shorter than 20 per cent are employed. It is the practice on a number of railroads to fix the minimum cutoff at around 25 per cent by blanking out the teeth

[1] This article is an abstract from papers entitled "Trends in Reciprocating Valve Mechanisms Employing Piston Valves," by Charles F. Krauss, assistant chief engineer, The Baldwin Locomotive Works, Philadelphia, Pa., and "Valve and Valve-Motion Design for Modern High-Speed Passenger Steam Locomotives," by A. G. Hoppe, assistant mechanical engineer, Chicago, Milwaukee, St. Paul & Pacific R.R. Co., Milwaukee, Wis., and discussions by L. B. Jones, engineer of tests, Pennsylvania R.R.; James Partington, manager of engineering department, American Locomotive Co.; W. E. Woodard, vice-president, Lima Locomotive Works; Frank Fisher, The Pilliod Co.; and R. P. Johnson, chief engineer, The Baldwin Locomotive Works; contributed by the Railroad Division and presented at the Semi-Annual Meeting, Milwaukee, Wis., June 17-20, 1940, of The American Society of Mechanical Engineers.

TABLE 1 VALVE DATA FOR RECENT AMERICAN HIGH-SPEED LOCOMOTIVES

Line no.	Type of locomotive	Diam of drivers, in.	Steam pressure, psi	Diam of cylinders, in.	Stroke, in.	Type of gear	Diam of valve, in.	Valve travel, in.	Lead, in.	Steam lap, in.	Exhaust clearance, in.	Max cutoff, %	Year built
1	4-4-2[a]	84	300	19	28	W	10	$6\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{4}$	85	1935
2	4-4-4[a]	80	300	$17\frac{1}{4}$	28	W	9	$6\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{4}$	84	1936
3	4-4-4	84	350	$17\frac{1}{2}$	28	W	10	7	$\frac{1}{4}$	$1\frac{5}{8}$	$\frac{1}{8}$	75	1935
4	4-6-2	80	205	27	28	W	12	7	$\frac{9}{32}$	$1\frac{5}{16}$	$\frac{1}{2}$–$\frac{9}{16}$	82	..
5	4-6-2[b]	80	260	23	28	W	12	8	$\frac{1}{8}$–$\frac{5}{16}$[b]	$1\frac{17}{32}$	$\frac{3}{16}$	..	1934
6	4-6-4[a]	84	300	25	29	B	12 & 14	$7\frac{3}{4}$	$\frac{3}{16}$	$1\frac{7}{8}$	$\frac{1}{8}$	73	1938
7	4-6-4[a]	80	285	22	30	W	11	$7\frac{1}{2}$	$\frac{5}{16}$	$1\frac{5}{16}$	$\frac{1}{8}$	..	1937
8	4-6-4[a]	84	300	$23\frac{1}{2}$	$29\frac{1}{2}$	W	13	7	$\frac{5}{16}$	$1\frac{1}{8}$	$\frac{1}{8}$	87	1938
9	4-6-4[a]	79	275	$22\frac{1}{2}$	29	B	14	$8\frac{1}{2}$	$\frac{1}{4}$	$1\frac{5}{8}$	$\frac{3}{16}$	82	1937
10	4-6-4[a]	78	250	25	28	B	14	9	$\frac{1}{4}$	$1\frac{3}{8}$	$\frac{1}{8}$	88	1937
11	4-6-4	79	225	26	28	B	14	9	$\frac{1}{4}$	$1\frac{3}{8}$	$\frac{1}{8}$	89	1930
12	4-6-4[a]	84	300	$23\frac{1}{2}$	30	W	12	$7\frac{1}{2}$	$\frac{5}{16}$	$1\frac{5}{16}$	$\frac{1}{4}$	84	1938
12a	Valve changes in locomotive of line No. 12						12	$7\frac{1}{2}$	$\frac{1}{4}$	$1\frac{3}{8}$	$\frac{3}{8}$	..	..
13	4-6-4[c]	84	350	19	28	W	10	7	$\frac{1}{8}$–$\frac{1}{8}$	$1\frac{11}{16}$	$\frac{1}{16}$	75	1935
14	4-4-4-4[d]	84	350	18	$26\frac{1}{2}$	W	10	7	$\frac{5}{32}$	$1\frac{3}{8}$	$\frac{1}{16}$	76	..
15	6-4-4-6[a,d]	84	300	22	26	W	12	$7\frac{1}{2}$	$\frac{5}{16}$	$1\frac{7}{8}$	$\frac{1}{4}$	70	1939
16	4-8-4	77	300	$24\frac{1}{2}$	32	W	12	7	$\frac{5}{16}$	$1\frac{3}{8}$	$\frac{1}{4}$	80	1937
17	4-8-4	80	300	25	32	W	12	7	$\frac{5}{16}$	$1\frac{3}{8}$	$\frac{1}{4}$	80	1939
18	4-8-4[a]	80	280	26	32	W	12	$7\frac{1}{4}$	$\frac{1}{4}$	$1\frac{3}{4}$	$\frac{3}{16}$	73.5	1937
19	4-8-4[a]	77	275	24	30	B	12	9	$\frac{1}{4}$	$1\frac{7}{16}$	$\frac{3}{16}$	..	1937
20	4-8-4	80	275	27	30	W	12	$7\frac{1}{2}$	$\frac{1}{4}$	$1\frac{3}{8}$	$\frac{1}{4}$	84	1938

W—Walschaert valve gear.
B—Baker valve gear.
[a] Streamlined.
[b] Variable lead: $\frac{1}{8}$ in. in full gear, $\frac{5}{16}$ in. at running cutoff.
[c] Double-ported valves.
[d] Four cylinders.

TABLE 2 VALVE EVENTS FOR A 4-6-4 LOCOMOTIVE[a]

	Preadmission, per cent		Port opening, in.		Cutoff, per cent		Release, per cent		Compression, per cent	
	Front	Back	Front	Back	Front	Back	Front	Back	Front	Back
Full gear	0.21	0.21	$2\frac{11}{32}$	$2\frac{17}{32}$	86.4	82.4	95.5	92.5	4.40	3.13
	0.73	0.62	$1\frac{3}{32}$	$1\frac{1}{4}$	65.5	64.5	85.3	82.8	10.41	8.58
Half stroke	1.67	1.25	$\frac{23}{32}$	$\frac{25}{32}$	48.4	50.5	76.0	74.5	16.10	14.40
	3.23	2.71	$\frac{15}{32}$	$\frac{31}{64}$	29.6	33.1	63.0	64.3	24.00	24.00
Quarter stroke	4.70	4.15	$\frac{13}{32}$	$\frac{25}{64}$	22.2	24.7	56.3	58.5	28.60	29.45
	6.27	5.43	$\frac{3}{8}$	$\frac{23}{64}$	18.1	19.6	52.2	54.0	32.20	33.30

[a] Valve dimensions and other proportions for this locomotive are given in line No. 12 of Table 1.

in the reverse lever quadrant between 25 per cent and mid-position. Consequently, such valve arrangements are not able to make full use of the expansive force of the steam when high admission pressures are used.

As a specific example, Table 2 shows the valve events for one side of the 4-6-4 locomotive described in line 12 of Table 1. If the cutoff is still further shortened to, say, 15 per cent, release occurs before mid-stroke, compression at about 35 per cent, and preadmission at about $7\frac{1}{2}$ per cent. Wire drawing at the short cutoffs and high speeds reduces seriously the area of the indicator card. This is most apparent at the cutoff and compression portions of the stroke, but does not appear serious at release.

In the example cited, cutoff is 25 per cent, although the point of valve closure is shown as about one-third stroke. Actual compression starts much earlier because of wire drawing, with the result that, coupled with the large lead and resultant early preadmission, the pressure at the end of the stroke is very high. This locomotive gave considerable trouble with main crankpins that ran hot and it was assumed that high compression pressures were primarily responsible. The valve setting was changed as shown in line 12*a* of Table 1, and, accordingly, the lead was decreased by $\frac{1}{16}$ in., the lap was increased $\frac{1}{16}$ in., and the exhaust clearance increased to $\frac{3}{8}$ in. No changes were made in the combination lever or the valve travel. As a result, at quarter stroke the preadmission was reduced to an average of 3 per cent, the cutoff reduced to 20.8 per cent, release reduced to about 53.5 per cent, and the compression to 25 per cent. This apparently helped the situation since the engines ran for a considerable period without undue difficulty with the pins.

SIZE OF PISTON VALVES

Increasing the size of the valve should provide a positive gain in port area but increases the weight and, consequently, inertia and frictional resistance. Although the use of high-pressure steam permits the use of small cylinders, which would seem to point the way toward small valves, it must be remembered that the density of steam increases with the pressure, and resistance to passage through the ports will be greater. Hence it does not follow that valves can be decreased in proportion as cylinder diameters are decreased for a given increase in working steam pressure. These facts are recognized, and the trend is toward consideration of larger valve diameters, although with reluctance to use them because of increased load upon the gear.

For high-speed locomotives it is obviously desirable to keep the weights of all reciprocating parts as low as possible. Therefore, the valve should be no larger than necessary to admit steam to, and to exhaust steam from, the cylinder. In considering the proper size of the valve it would appear that in the majority of the cases the controlling factor is the size of the port between the cylinder and the steam chest. It is quite obvious that if, in a conventional cylinder, clearance volume is kept to a definite value, the size of the cylinder port is more or less fixed. Some designers base the valve diameter entirely on the relationship between the area through the cylinder port and the exhaust opening at the end of the stroke. The diameter of the valve is fixed so as to provide about six per cent more exhaust area through the bushing ports than the area through the cylinder port.

Undoutedly, the final choice of a valve diameter is a com-

promise and is determined on the basis of either the steam- or exhaust-port areas, whichever the designer decides is the more important. It is understood, for example, that in the case of the engine in line 6 of Table 1, several locomotives were furnished with 12-in. valves, and the remainder with 14-in. valves. Information now available indicates that there is no noticeable difference in the performance of the locomotives.

LONG VALVE TRAVEL AND LARGE LAP

With valve travels of $8^1/_2$ and 9 in., and steam laps of $1^7/_8$ or 2 in., it is possible to obtain greatly improved valve events with either the Walschaert or the Baker gear. Naturally, the longer valve travel produces faster valve action but at the same time causes some additional stresses in the valve gear because of increased inertia and resulting heavier load upon the gear parts. However, because of the improved port opening and general improvements in valve events, it is possible that a locomotive with 9-in. valve travel and a $1^7/_8$ or 2-in. steam lap could be operated at cutoff somewhat shorter than 25 per cent.

More attention has recently been given to valve setting to obtain greater port opening at short cutoff, and the increased lap necessary to accomplish this has resulted in maximum cutoff in the neighborhood of 82 per cent instead of 88 per cent as was formerly common, but with no apparent loss in starting power, even though locomotives still continue to be rated at 85 per cent mean effective pressure. Further improvement along these lines, by attempting to employ still shorter maximum cutoffs, is, however, greatly limited because of increased piston load and correspondingly heavier revolving and reciprocating machinery.

VALVE DETAILS

The weight of the valve-gear parts themselves is an important factor, and the trend is toward lightweight gears employing special steel in all parts except the eccentric rod which sometimes must be adjusted in order to square the valves. Recent practice has abandoned the use of cast-steel and cast-iron valve spools and encouraged the substitution of lighter-weight valve spools constructed of tubing and forged ends. For high speeds and high superheat bronze sectional packing rings, with the tension provided by a separate alloy-steel spring especially designed for high-temperature service, appear to be satisfactory. On several recent orders for locomotives, the valve bushing is kept in position by providing it with two or three lugs which extend to within $^1/_{32}$ in. of the valve-chest heads. The bushing plug is still retained to prevent the bushing from turning in the valve chest.

The most important advance in valve-gear design itself is the tendency toward the use of antifriction bearings at all pin connections, which, by elimination of accumulated slack, goes a long way toward reducing the impact load upon the component parts of the valve gear; and what is equally if not more important, is the assurance given that steam distribution will be consistent with the cutoff position of the reversing gear.

On Walschaert gears the link block remains a problem, as no means have yet been found to provide a rolling contact between the block and the slot in the link. A satisfactory solution would be a welcome improvement and a step forward in valve-gear design.

VARIABLE LEAD

Variable lead frequently comes up for discussion and has been applied in actual practice. A case in point is the locomotive described in line 5 of Table 1, which was provided with a $^1/_8$-in. lead in full gear and $^5/_{16}$ in. at running cutoff. The simplest method of accomplishing this is by increasing the length of the eccentric crank, which is not objectionable in a passenger locomotive since the accompanying distortion in the back-up motion is not serious.

POPPET VALVES

Several attempts have been made in this country to apply to existing designs of locomotives poppet-valve arrangements similar to those used in Europe. The results have not been especially successful. However, one railroad has two such locomotives which have been in service for several years with good success. Another railroad is trying out a poppet-valve mechanism of American manufacture, but so far operating data on it are not available.

There is no question that the poppet valve with independent adjustments of valve events definitely overcomes the principal shortcomings of the piston valve with the conventional Walschaert or Baker gear. Thus, at 25 per cent cutoff, where the piston valves release at between 50 and 60 per cent of the stroke, it is possible with poppet valves to carry the expansion to almost 90 per cent. Under such an arrangement, an engine with chest pressure of 285-psi and 25 per cent cutoff will show on a theoretical indicator card at a release of about 56 per cent a pressure of 125 psi. The same expansion curve carried out to 90 per cent release will show about 75 psi at this point. Similarly, while the piston valve closes at anywhere up to 30 per cent of the stroke, it is possible with the poppet valve to reduce this to 15 per cent. Furthermore, with the faster action of the poppet valve, wire drawing is greatly reduced with resultant increase in area of the indicator card at the cutoff and compression ends of the stroke. Therefore, it appears that if the American railroads are to make the fullest use of the higher boiler pressure, it will be necessary to employ valve arrangements which permit the practical use of cutoffs shorter than 25 per cent and which, at the same time, will permit release at somewhere near 90 per cent of stroke. With poppet valves, cutoffs as short as five per cent have been used successfully.

Another advantage of the poppet valve is the greatly reduced power required for the operation of the mechanism. It has been estimated that the ordinary Walschaert or Baker gear will require from 50 to 60 hp for its operation, while power measurements made on the American poppet-valve gear previously mentioned show this to run between 3 and 4 hp at 500 rpm of the crankshaft. The use of lifting, instead of sliding, valves also decreases the danger of "stuck" valves caused by carbonization.

The reasons why poppet valves have not been used as extensively in this country as in Europe are the large size of American locomotives and the volume of steam to be handled, necessitating either a very large valve or the use of multiple valves. Consideration of poppet valves has so far been confined to locomotives intended for schedules requiring speeds of 100 mph or more, in which case positive seating of the valves is a difficult matter. Also, the movement at the stem which can be imparted by the conventional Walschaert gear, even through the use of cams, is not adapted to produce the most economical steam distribution at all cutoffs. Steam passages for poppet valves should be, if anything, more liberal than for piston valves, so that full advantage of the increased port areas obtainable with poppet valves can be realized.

ABSTRACTS FROM DISCUSSION

L. B. JONES. Of particular interest in valve-gear design are the oscillograms in Fig. 1, showing measured and calculated stress in the lap and lead lever of a Walschaert valve gear. The dotted line showing calculated stress is based on inertia forces only with no attempt being made to evaluate the friction of the valve. Solid lines show the rapid and violent fluctuations under actual stress measured by means of a strain gage mounted on the lap and lead lever.

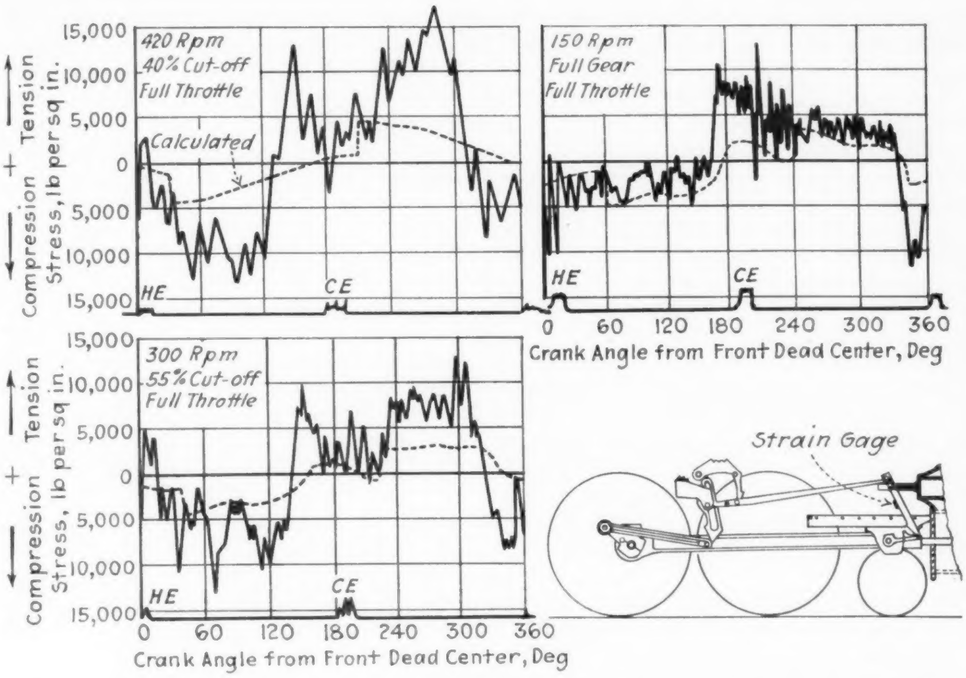


FIG. 1 COMPARISON OF MEASURED AND CALCULATED STRESS AT VARIOUS SPEEDS WITH WALSCHAERT VALVE GEAR AT BACK OF LAP AND LEAD LEVER 9 IN. BELOW CROSSHEAD PIN WITH 12-IN. PISTON VALVE

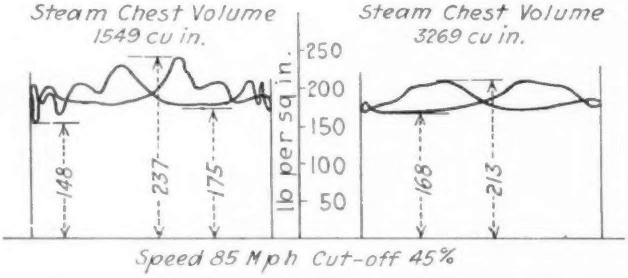


FIG. 2 VARIATION OF STEAM-CHEST PRESSURE WITH DIFFERENT STEAM-CHEST VOLUMES

As brought out by one of the authors, there is also need for a better design of steam passages and, particularly, steam-chest volume. In support of this contention, Fig. 2 is presented showing steam-chest indicator cards taken on the same locomotive at the same speed and cutoff, but with different steam-chest volumes. With the restricted volume, the maximum fluctuation in steam-chest pressure is from 148 to 237 psi, whereas with the enlarged volume, which is normal for this locomotive, the maximum fluctuation is from 168 to 213 psi. The pressure surge which follows the closing of the valve is noteworthy and indicates that the steam flow in the passages builds up a high velocity while the valve is open, reaching its maximum at the time the valve closes. Larger steam passages would reduce this velocity somewhat, but the most helpful step is to increase the steam-chest volume so that the velocity fluctuations in the steam passages are not only ironed out but the admission line on the cylinder indicator card is also substantially raised.

JAMES PARTINGTON. One of the limiting features inherent with valve gears of the Walschaert type is compression, which increases as the cutoff is shortened. If it is to be controlled, some accurate and inexpensive test should be devised to measure the final compression to see that it does not exceed the steam-chest pressure when the locomotive is producing the speed and power desired. Present expensive indicator tests are often inaccurate at high speeds in giving the correct final compression pressure. It has been found that the "loops" obtained on some indicator cards are not caused by high compression in the cylinder but rather by the impulse set up in the pipes connecting the cylinder with the indicator.

One possible inexpensive test of compression can be conducted without the use of a driving mechanism for the indicating instrument. A special gage could be applied directly to the cylinder and connected electrically to a receiving instrument in the cab. In operation the train could be brought to the required speed with a wide-open throttle. Then by slowly closing the throttle the instrument in the cab would indicate when the steam-chest pressure had fallen below the predetermined setting at the cylinder indicator, perhaps 10 psi under normal steam-chest pressure with a full throttle. If the steam-chest pressure gage showed that the pressure there had fallen below the predetermined setting and the instrument in the cab indicated that the pressure in the cylinder still exceeded the predetermined pressure, it would be apparent that the compression was excessive. If the cab instrument showed that the compression was not exceeding the predetermined amount at the running cutoff, then by shortening the cutoff, the point could be found where the resulting compression did equal it. By means of this information it might be possible to reduce the exhaust clearance and gain a longer expansion period, knowing that the final compression pressure could be kept below that of the steam chest.

The American Locomotive Company has recently adopted a graduated series of valve sizes and settings for high-speed locomotives. These arrangements are designed to give port openings consistent with their corresponding cylinder diameters and to cause the individual valve events to occur at approximately the same crank angles for all settings. Valve settings give maximum cutoffs of 83 or 84 per cent while exhaust-port openings through the valve bushings vary from 11 per cent of the piston area for large cylinders to 12 or 12.5 per cent for small cylinders. This area is taken when the piston is at the end of its stroke and the valve is open to the exhaust, a distance equal to the lap, plus the lead and the exhaust clearance. These proportions, if used with suitable design of piston and cylinder heads, will involve a cylinder clearance volume varying from approximately 10 per cent for a 32-in-stroke cylinder to 10.5 per cent for a 28-in-stroke. The ratios for valve diameters are almost 1 : 2, as follows: 10-in-diam valve for 18 to 20-in-diam cylinders, 11-in. for 21 to 22-in., 12-in. for 23 to 25-in., 13-in. for 26 to 27-in., and 14-in. for 28 to 30-in.

FRANK FISHER. With the use of long valve travel and long steam lap, the following advantages are obtained: Increased expansion, steam-port opening, and exhaust-port opening; reduced preadmission and compression; and shorter cutoff operation. Longer steam lap is very essential with the high-pressure boilers because of the necessity of reducing the preadmission to

the lowest point possible. In the writer's opinion, it is not good practice to admit steam on the negative side of the piston through 3 to 4.5 per cent of the stroke at 285 psi, while on the opposite side of the engine on the positive side of the piston the pressure is 160 psi. Improved steam distribution is sacrificed by the use of short valve travel and lap because a locomotive is only operated in full gear with long valve travel for a few revolutions of the drivers in the starting of trains, which is a very small percentage of its mileage. It is possible to make better use of high-pressure boilers with the present types of valve arrangements by utilizing larger steam lap and longer valve travel.

The use of poppet valves evidently does not eliminate all the difficulties encountered with high-pressure boilers since a number of locomotives recently built in Europe, where poppet valves have been used extensively, have conventional piston valves. The writer does not think it possible to use nearly 90 per cent release and 15 per cent compression at running cutoff in high-speed service because, even with poppet valves, it takes time for the exhaust steam to be removed from the cylinder and a certain amount of compression to cushion the reciprocating parts and the main rod.

R. P. JOHNSON. The experience of excessive compression and the accompanying pound in the locomotives remains with the operating staff of the railroads, and has resulted in the more or less common practice of limiting cutoffs to not less than 25 per cent and, in some cases, as high as 33 per cent of the stroke, and regulating power and speed requirements by the throttle.

With modern locomotives equipped with ample passages, large nozzle and correspondingly large stack, this does not hold true, and for light powers at high speeds it is possible to use cutoffs as low as 10 or 12 per cent without excessive compression. In fact, the degree of compression obtained is needed to cushion the centrifugal force of the reciprocating parts and the main rod, relieving the main crankpin from what at high speeds is often a force greater than the maximum piston load which in actual practice has, in a few cases, resulted in overheating the main crankpin bearing. A recent case is that of a group of recently built 4-8-4 type locomotives, on which, following the practice of the railroad, the reverse lever quadrants were so arranged that the minimum cutoff was limited to 33 per cent of the stroke. Due to reduced traffic, relatively light trains were handled. Under these conditions the power at minimum cutoff greatly exceeded the requirements, forcing the engineer to work at a very light throttle. There being little or no compression, excessive loading and overheating of the crankpin bearing resulted, a condition which was fully overcome when the locomotives were arranged for, and operated at, shorter cutoff and full throttle.

It is a recognized fact that with radial valve gears, if a high-capacity locomotive is to deliver its maximum power at high speeds, it becomes necessary to employ a cutoff longer than the theoretical one required to take care of the evaporative capacity of the boiler. While this is not a desirable condition and is one of the primary reasons for the endeavor to utilize poppet valves, it, nevertheless, automatically reduces the hazard of high compression since, with the advanced cutoff, the point of compression is delayed.

Floating Power Plants

WISCONSIN UTILITIES ASSOCIATION

FLOATING power plants which can be towed through America's coastal and inland waterways and hooked up to regular distribution lines to generate electricity in an emergency may be a factor in the National-Defense program, according to A. P. Kellogg of the General Electric turbine division.

Speaking before the Wisconsin Utilities Association at Milwaukee, Nov. 12, A. P. Kellogg, of the General Electric Company, said that a recent study showed a large portion of the eastern United States and the West Coast could be reached by generating stations housed in vessels designed to pass through the New York State Barge Canal.

A projected 50,000-kw self-contained floating power plant is being studied, Mr. Kellogg said. This seems to be the largest rating practicable. The equipment in general closely follows standard marine and central-station practice with modifications necessary to meet low headroom.

The complete 50,000-kw steam-generating station he described could be housed in a hull similar to that of a lake freighter. Dimensions of the vessel were limited to an over-all length of 290 ft, a 43-ft beam, 10-ft draft, and a low bridge clearance of 15 ft.

The idea of floating power plants is not new. The U.S.S. *Lexington*, a turbine-electric-drive battleship, supplied much needed power to the City of Tacoma, Washington, in 1929 when a shortage of water reduced the power supply below the city's requirements. Two 10,000-kilowatt turbine generators were installed in the hull of the *Jacona*, a ship built during the last war, and it has been used by the Public Service Company of New Hampshire as a floating power plant since 1930 in New England. At present it is in service on the Piscataqua River near Portsmouth, New Hampshire.

In describing the 50,000-kw floating power plant, Mr. Kellogg said that four boilers would be used. These would be similar to the standard oil-burning marine-type boiler, with the addition of an air preheater and a somewhat smaller economizer. The stacks would be made with separable connection so that they could be removed for transportation beneath bridges.

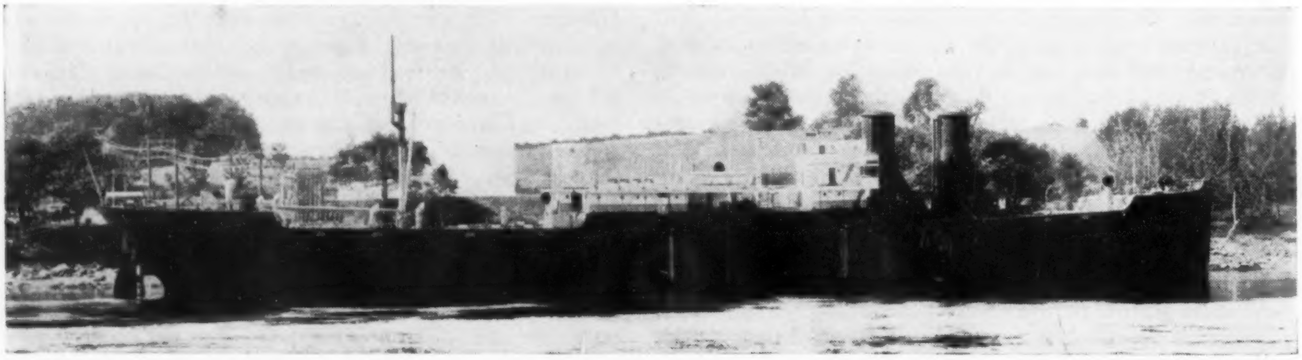


FIG. 3 FLOATING 20,000-KW STEAM-ELECTRIC POWER STATION "JACONA" OF PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE

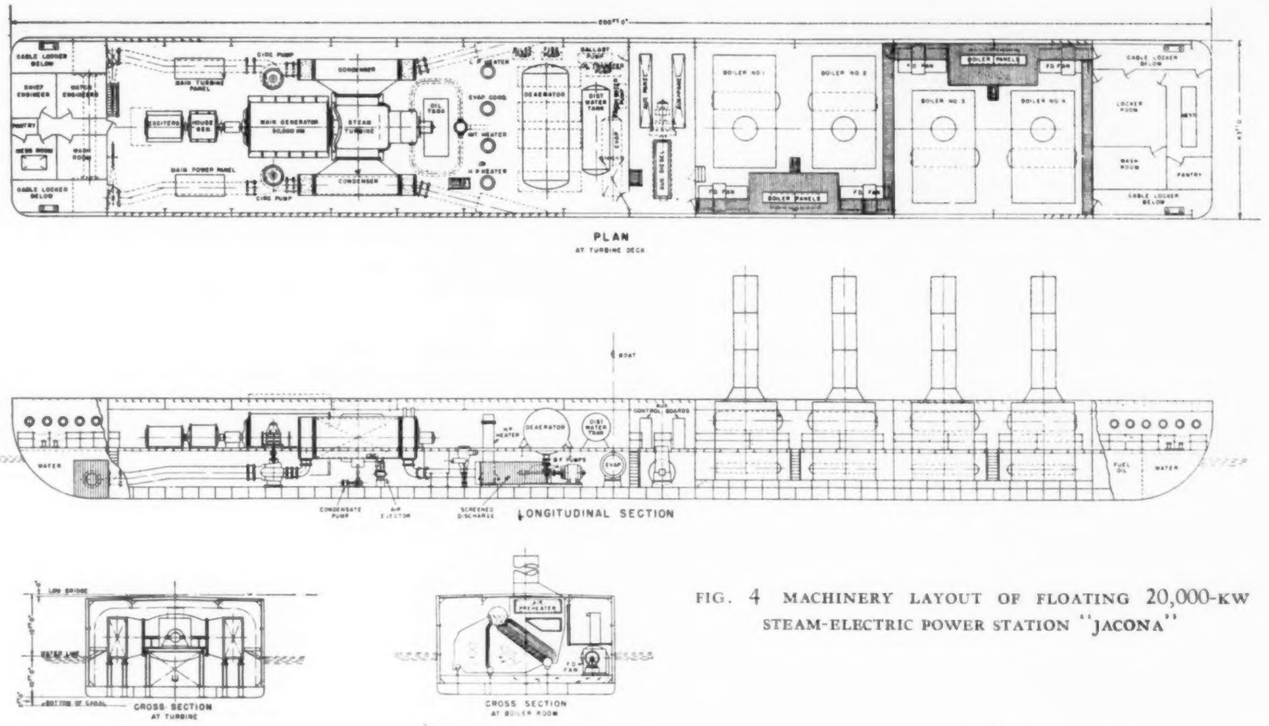


FIG. 4 MACHINERY LAYOUT OF FLOATING 20,000-KW STEAM-ELECTRIC POWER STATION "JACONA"

The steam turbine would be direct-connected to the main generator and a house generator which would carry the auxiliary load. It would operate at 3600 rpm and be of the tandem-compound type, double-flow with side exhausts. The steam cycle could be comparable with standard central-station practice, with the same steam pressure and temperature and full feedwater heating system.

The main generator would be rated 50,000 kw, 0.8 power-factor, 62,500 kva, 3-phase, 60 cycles, 13,800 volts. Direct-connected to the main generator would be a house generator rated 3500 kw, main and pilot exciters, and a house exciter. The main generator would be hydrogen-cooled with the surface gas coolers within the generator casing. A surface air cooler would provide cooling air for the house generator.

The condensers would be horizontal-tube, single-pass, similar to the usual central-station design, except that the steam connections would be at the side.

Auxiliary equipment would be similar to the usual central station, with feedwater heaters, deaerator, make-up water and storage tank, fuel oil pumps, boiler feed pump, and forced-draft fans.

So that the unit could be started from cold, an auxiliary Diesel-driven generator of approximately 500-kw capacity would be included. Some lights and a small amount of power would probably be required while the vessel is being towed and a gasoline- or Diesel-driven generator of about 20 kw would be needed for this purpose.

Fuel-oil and fresh-water tanks to be carried in the hull would have a capacity for 10 to 15 hours' operation, so that the floating power plant could operate immediately on its own until a supply tanker could be brought alongside.

Plans for the hull also call for a double bottom for fuel or water storage or ballast, which would permit lightening the vessel to get over shallow draft points or taking on extra weight to get under low bridges.

Mr. Kellogg stated that the operation of such a plant would be comparable with that of a good, modern central station. Performance at full load is estimated at 12,000 to 12,500 Btu per kwhr, figured on the basis of power output from the vessel and including all auxiliary requirements.

Engineering Students, 1940-1941

THE JOURNAL OF ENGINEERING EDUCATION

ACCORDING to figures published in the December, 1940, issue of *The Journal of Engineering Education*, the total 1940-1941 enrollment in 155 institutions in the United States and Canada is 110,618. Of these, by far the largest number, 28,609, are in mechanical-engineering courses. Enrollments in other engineering courses are: Aeronautical, 3723; agricultural, 864; architectural, 1119; ceramic, 730; chemical, 16,177; civil, 11,152; electrical, 15,505; industrial, 2442; metallurgical, 2276; mining, 2294; and unclassified, 25,727. The total enrollment in 146 institutions reporting in 1939 was 105,892 undergraduate engineering students.

Enrolled in these same schools for work leading to the master's degree are 4589 students, and for the doctor's degree, 623 students. In graduate engineering enrollment, however, mechanical engineering (895 master's, 48 doctor's) is edged out by chemical engineering (910 master's, 237 doctor's), and electrical engineering (984 master's, 120 doctor's). Other graduate enrollments are: Aeronautical, 130 master's, 24 doctor's; agricultural, 28 master's, 3 doctor's; architectural, 21 master's, 1 doctor's; ceramic, 14 master's, 20 doctor's; civil, 603 master's, 66 doctor's; industrial, 178 master's, 2 doctor's; metallurgical, 216 master's, 49 doctor's; mining, 63 master's, 7 doctor's; and unclassified, 556 master's, 46 doctor's.

The largest undergraduate enrollment is at the Illinois Institute of Technology (formerly Armour Institute and Lewis Institute), 4087. The next largest enrollments are at Purdue, 3487; City College, New York, 3278; and Texas A. and M., 3101. High graduate engineering enrollments are at Massachusetts Institute of Technology, 333 master's, 122 doctor's; New York University, 348 master's, 23 doctor's; Illinois Institute of Technology, 328 master's, 13 doctor's; Stevens, 337 master's.

Engineering schools in the United States conferred 11,358 and those in Canada 166 first degrees during the academic year 1939-1940, a total of 12,524. In the same year these schools conferred 1326 master's degrees (1318 in United States) and 108 doctor's degrees.

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Is Engineering a Profession?

FOR several years, in fact for more than thirty years, I have been interested in finding an answer to the question, "Is Engineering a Profession?" and I note with great interest the present recurrence of discussion on this point. I venture to make the following comments largely because I have a sort of binocular perspective of the question. For twenty-four years I have been a member of the bar and at the present time I am a more or less active member of four bar associations. I have served on bar-association committees and attended many conferences at which I have heard professional problems discussed. I have been a member of the A.S.M.E. and a fellow of the A.I.E.E. since before I was admitted to practice law. I therefore can speak in the dual capacity of an engineer and a lawyer familiar with the problems of a recognized profession.

The definition of "professional" copied from Webster by Mr. Logan in your November issue[1] is a good one in that it defines professional as "conforming to the rules or standards of a profession; following a profession or some line of conduct as if it were profession." This definition is good because it ignores the question of education and experience. The engineer who has spent as much time and effort as the lawyer or doctor in getting his education is inclined to cite this fact in support of his claim to being a professional man. Every educated man is not necessarily a professional man and the fact that today no one can enter some professions without receiving an education equal to that required for an engineering degree does not necessarily establish that anyone having an equivalent education is necessarily a member of any profession.

A man enters any profession by proving himself fitted to practice it, but he stays in it by conforming strictly to certain rules of conduct. These rules may be grounded upon common morality but they go further than that. One of the most potent facts tending to show that the average engineer is not a professional man is that he sees no need for any such rules. He thinks it is enough to be honest. Ordinary personal or business honesty is comparatively easy. Professional honesty is not so easy, in fact, it requires constant vigilance and, at times, a very highly developed sense of professional ethics to be absolutely honest professionally.

The professional relationship presupposes the existence of a principal, called a client or patient, and an agent, called a lawyer or doctor, for example. The agent is employed by the principal. This professional relationship goes beyond the ordinary relationship of employer and employee in that it is a fiduciary one. The principal can confide to the fullest extent in the agent and the agent is bound, not only not to violate this confidence, but never to use it to the detriment of his principal. This obligation is a permanent one. The principal can acrimoniously discharge the agent, he can refuse to pay him, he can circulate lies about him, and the agent is not thereby freed of his professional obligation. The relationship is always a personal one in that the agent cannot be a corporation and the obligations assumed are the personal obligations of the agent himself. The agent cannot quit the employ of the principal and get a new job at higher pay where he can use the knowledge he got from the principal for the benefit of another principal.

The professional man is not only bound by his fiduciary relationship to the client, but he also owes certain duties to the public. He cannot advertise, he cannot solicit employment, and he cannot employ salesmen to sell his services. A lawyer is an officer of the court and owes a duty to the public subordinate, but similar, to that owed by the judge. An important characteristic of any professional man is that he is subject to professional discipline. If he does not comply with the rules of his profession, he can be put out of the profession and barred from further practice.

Finally and most important, the practice of law, for example, is confined by law to members of the bar, that is, to those who have passed rigorous bar examinations, who have accepted and followed the rules of conduct of the bar, and who can be excluded from further practice for unprofessional conduct. The records of the bar associations show that the right of disbarment and the right to prevent persons not members of the bar from practicing law have been often exercised. It is hard to see how the rules of conduct could be enforced unless the bar associations had both these rights.

This does not answer the question as to whether or not an engineer is a professional man. As to this it may be said that if the engineer is a professional man, he must be a member of a profession. There is nothing about engineering that sets it apart as a profession In spite of the licensing laws in many states, almost anyone can practice engineering. If we adopt the old definition of engineering as the control of the forces of nature for the benefit of mankind, or even a narrower definition, it is hard to see how we can restrict the practice of engineering to any group. We can restrict the use of the title "engineer" to such a group, but the practice of engineering, in any broad sense, is one of those inalienable rights common to mankind. Just where tinkering stops and engineering begins is hard to say.

It is interesting to wonder whether or not engineering could be established as a profession, but the fact remains that it has not been so established. Anyone can practice it unhampered by any rules of conduct and without fear of punishment. No one can be excluded, and without some right of exclusion or some other means of punishment rules of conduct are of no value.

If the engineers wish to call themselves professional men, no one is going to object. They cannot, however, actually become professional men unless they first establish engineering as a profession, and unless, having established the profession, they adequately police it. Whether or not they should do so is quite another question. If they do so, they will discover a lot of things as to which they are now happily ignorant, and they will find themselves prevented from doing many things they now do.

Personally, I believe in the professional status. I am not in favor of anything that gives any profession economic ad-

[1] "Unionization of Engineers," by Orwell Logan, Mechanical Engineering, November, 1940, pp. 827–828.

vantages. I am in favor of anything that raises professional standards and enables the profession to insure that the public will get better service. It is only by insuring such better service that any profession can justify its right to exist. In as far as, and no further than, the establishment of engineering as a profession will insure better engineering at lower cost, I am in favor of it. In as far as it may be directed to getting engineers higher pay, shorter hours, or the right to restrict production, I would be against it.

Contrary to popular opinion, the bar associations have never interested themselves primarily in the problem of improving the economic position of the lawyer. They have consistently taken the stand that if we have better lawyers and better legal procedure, the lawyers must benefit automatically. Their attitude is very similar to that of the A.S.-M.E., which assumes that the more mechanical engineering advances, the better off the engineers will be. In the engineering societies the engineers have a nucleus around which they could build a profession. Their work has not, however, progressed to a point at which, in my opinion, they can be truly said to have one. This does not, of course, mean that I think any the less of them for this. A man is judged by what he is and what he does, and the engineers have every reason to be proud on both counts.

FORD W. HARRIS.[2]

Control of Gases in the Wake of Smokestacks

COMMENT BY A. D. BAILEY[3]

The investigation described in this paper[4] was a successful and worth-while undertaking. It came about as the result of the action of the gases leaving the stacks of the Crawford Station of the Commonwealth Edison Company, Chicago, Ill.

The stacks at this station are unusually large, one being 26 ft in diam at the base, and the other three 30 ft, all tapering slightly toward the top. When the station was built in 1924, the first stacks were 190 ft high above the ground; they were subsequently increased to 250 ft in height. As succeeding stacks were built, they were of this height also. In 1933, consideration was given to increasing these stacks to 300 ft, which was the limit permitted by the design of the stack structure. However, as this was rather an expensive undertaking, it seemed advisable to ascertain the cause of the trouble; the research described by the authors was the result.

For several years we had been making observations of weather conditions at the station and had records of wind velocities, atmospheric pressures, the height of the gas tanks to the southwest, the amount of gas leaving the stacks, etc., but from the observations alone it was impossible to develop a remedy for the trouble. As the work progressed with the small model in the wind tunnel at the University of Michigan, it was found that the model results checked very closely the observations made at the plant. It soon became apparent that the large diameter of the stacks, the wind velocity, and the exit velocity of the gases from the stacks were the three important factors.

In 1938, the height of the stacks was increased to 300 ft as shown in Fig. 7, of the paper. The results have been gratifying not only to our organization, but to F. A. Chambers, deputy smoke inspector in charge, Department of Smoke Inspection and Abatement, Chicago, as well. He has stated that complaints have practically ceased since the stacks were raised.

We have recently built one new stack in which the principles laid down by this investigation were followed. This stack is 300 ft in height, with an inside diameter of 13 ft; the exit velocity of the gases is 50 ft per sec. We also have under construction an installation in which there will be one stack for each boiler. These stacks will be 300 ft in height, with an inside diameter at the top of 9 ft, and an exit-gas velocity of 55 ft per sec. In these stacks, the benefit to be derived is twofold, since we are not only avoiding the large stack which because of its large diameter produces serious eddies in its wake, but the exit velocity of the gas has been raised to a point where it is carried clear of any eddies which may form.

The writer wishes to acknowledge the interest and cooperation of Mr. Chambers and his department in this investigation and in its results. He followed the matter personally and is as gratified with the results attained as we have been.

COMMENT BY R. D. CONRAD[5]

The authors state that there are no important errors introduced by aerodynamic scale effects, and an explanation of the basis for this statement would be most desirable as a substantiation of the experiments. It can hardly be established, a priori, that the model performance is a faithful replica of that of its prototype in this case. Obvious probable sources of scale effect include:

(a) The turbulence in the wind-tunnel stream, as compared to that of the open air; i.e., the so-called "effective Reynolds number" of the experiments.

(b) The characteristics of the smoke: density, viscosity, and particle size.

(c) The thermal factors: temperature of the model stack gases, heat transfer, velocity of the model gas induced in the model stack, as compared with the prototype.

It would appear that the question of similarity could in this case be settled only by experiment, and would involve a choice between duplicating model tests on various scales, or taking accurate full-scale data for comparison with model results.

Hydraulic engineers are faced with similar difficulties in the model study of bed-sediment movements of rivers. Confidence in model results is obtained when actual measurements of the shift of the full-scale sediment are duplicated, within the required accuracy, by the model river and, in new problems, the accumulated experience gained from former studies determines the model technique. The same verification process is used, in general, in ship- and airplane-model testing.

The subject experiment ventures into much less familiar fields of similitude. Since the prototype was altered as the model results showed to be desirable, and since (presumably) the nuisance of stack-gas downwash was abated, one may be tempted to accept the outcome as proof of the means. But it is more important, from a scientific viewpoint, to examine the reliability of the method quantitatively, and to establish the degree of reliability which can be placed in such experiments.

AUTHORS' COMMENT

The statement was made in the "Summary of Conclusions," item 6: "The downwash observed with models is substantially the same as that which would be observed in the field for the same wind velocity, stack-gas velocity, and gas temperature, that is, there are no important errors introduced because of aerodynamic scale effects." The validity of this conclusion is not by any means self-evident and R. D. Conrad and Charles E. Lucke (the latter by mail) raise some perti-

[2] Harris, Kiech, Foster & Harris, Los Angeles, Calif. Mem. A.S.M.E.

[3] Chief operating engineer, Commonwealth Edison Company, Chicago, Ill. Fellow A.S.M.E.

[4] "The Control of Gases in the Wake of Smokestacks," by R. H. Sherlock and E. A. Stalker, MECHANICAL ENGINEERING, June, 1940, pp. 455–458.

[5] Lieutenant, United States Navy, United States Navy Yard, Mare Island, Calif.

nent questions regarding the basis of the statement. A discussion of this point was omitted from the original paper due to space restrictions and a full discussion cannot be given here for the same reason. However, a complete report is published elsewhere[6] and is abstracted as follows:

This project was not concerned with such questions as the flotation and diffusion or dispersion of gases in the free air or with the translation and deposition of dust particles. These questions have been treated at length by others and are not materially involved in the phenomenon of downwash in the aerodynamic wake. Their variables, therefore, should not enter into the consideration of similitude on this project.

Similitude here must be divided into two parts corresponding to the two stages of downwash, namely, that involving the rectangular sharp-edged buildings, and that involving the cylindrical stacks where sharp edges are encountered only where the air flows over the tops of the stacks.

It has been shown experimentally by Irminger and Nokkentved[7] that scale effects need not be considered in relation to the pressures on flat roofs and on the leeward side of buildings. The separation of the surface layers always occurs at the corners and there is, therefore, no critical value of Reynolds' number at which the coefficients of air resistance undergo changes in these regions; in fact, the coefficients will depend only upon the shape and proportions of each building and its model. It was assumed on this project that the type of flow which accompanies these pressures would likewise remain the same for model and prototype, and that this similarity would apply also to questions of downwash within the wake.

There remained then, only the cylindrical stacks. With them we were interested in knowing whether (*a*) an observed depth of downwash at the model would be reproduced to scale at the full-size stack; (*b*) the wind velocity and the stack-gas velocity required scale-reduction factors; (*c*) the stack-gas temperatures involved scale effects between model and prototype. The variables which may be assumed to be involved in the first step of downwash are listed with their fundamental dimensions of length, time, and temperature, as follows:

Variables	Symbols	Dimensions
Depth of downwash...	l	L
Diameter of stack.....	d	L
Wind velocity........	v_1	LT^{-1}
Gas velocity............	v_2	LT^{-1}
Gas temperature......	θ	θ

The functional relation between the variables is given by the equation

$$l = f(d, v_1, v_2, \theta)$$

Both sides of the equation must have the fundamental dimension L regardless of the size of the units in which the variables are expressed, that is, regardless of the scale of the model or its prototype. This can only be true when the variables inside the functional sign are rearranged. The term θ must be dropped, since none of the other variables contains the dimension of temperature and since there is no other variable having this dimension which might conceivably be added; there is, therefore, no arrangement which would cancel it.

$$\text{Hence} \quad l = f\left[d, (v_1)^n, \left(\frac{1}{v_2}\right)^n\right] \ldots\ldots [1]$$

It is seen that the depth of downwash depends only upon d, v_1, and v_2 and that θ cannot enter into the relationship directly as a variable. However, temperature may have an indirect influence on the effective value of v_2 due to the change of volume which accompanies the mixing of the hot gases with the cold air as the gases emerge from the top of the stack. Experimental results with the model show that, for a constant weight of gas, changing the temperature has a negligible effect upon the depth of downwash. This is shown in Fig. 2 of the paper by dotted lines and is discussed fully in the bulletin[4] mentioned. There is no reason to expect this indirect temperature effect to be any more important when the number of units of measurement is changed to fit the prototype. Therefore, it is proper to proceed on the assumption that the depth of downwash is some function of d, v_1, and v_2, as given in the foregoing dimensionally homogeneous equation, and that the indirect effect of temperature will be adequately included in the experimentally derived values of the functional expression.

It was shown experimentally that, within the limits of experimental error, no scale-reduction factor is required for d and v_1. This was done by measuring the angle and intensity of downflow throughout the wake of the stack. No difference in behavior was found above and below the critical range of Reynolds' number. Since the kinematic viscosity of air may be considered constant on this project, the only variable entering into Reynolds' number is the product of wind velocity and stack diameter. This product gives values below the critical range for the model and above it for the full-size station, and these tests show, therefore, that there will be no substantial differences in the air downflow, induced by the stacks of the model, as compared to those of the station. In other words, they show that the form of the function in Equation [1] is not changed by changes in the scale of d and v_1.

It may be concluded for these two variables d and v_1 that whatever differences exist between the detail structure of flowing air behind the model stacks and their prototypes in the field, these differences do not destroy the characteristics of the downflow which are essential to downwash. There may be differences in the relative frequency of the eddies, or in the paths which they follow downstream, or in the relative size and strength of the individual eddies, but the effect of their presence upon air downflow is practically the same in both cases.

The extent to which the velocity of the stack gases at the models enable them to escape the influence of the downflow induced by the stacks is shown in Figs. 2 and 3 of the paper. The escape depends upon relations between v_1 and v_2. It was not practicable to conduct tests above the critical range to show that these relations also hold true for the full-size stacks, since the available heating and venturi apparatus did not have sufficient capacity to control the temperature and velocity of the large volume of air and gas that would be required. There is therefore no direct experimental evidence to show that these relations between v_1, v_2, and l are free from scale effects.

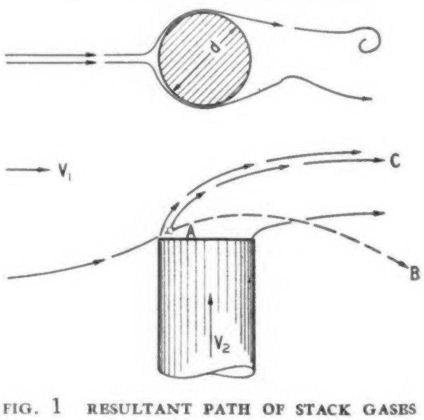


FIG. 1 RESULTANT PATH OF STACK GASES IN THE WIND

In making recommendations for remodeling the stacks, it was necessary to rely upon general considerations to cover this point. For example, Fig. 1 of this comment shows the flow conditions at the top of a stack. If a parcel of gas appears

[6] "A Study of Flow Phenomena in the Wake of Smokestacks," by R. H. Sherlock and E. A. Stalker, Engineering Research Bulletin No. 29, University of Michigan, Ann Arbor, Mich.

[7] "Wind Pressure on Buildings," by J. O. V. Irminger and Chr. Nokkentved, Danmarks Naturvidenskabelige Samfund, Copenhagen, 1936.

at A without vertical velocity v_2 it will follow the path of the wind AB and become involved in the downflow induced by the eddies in the wake. If some vertical velocity exists, however, then the parcel will follow the resultant path AC. If the ratio of v_2 to v_1 is large enough, all parcels of gas will follow paths which are high enough to escape the downflow in the wake. It is well established that there are no appreciable scale effects in the flow over sharp-edged bodies and it may, therefore, be said that the path of the wind over the top of the stacks, due to v_1, is free from scale effects. There can be no scale effects in regard to v_2 except possibly a slight difference in the distribution of velocities at the model and at the station. Therefore, there can be no scale effects in the resultant path of the gas, since there are none in either of its two components v_1 and v_2. Hence, the escape of the gas from the downflow in the wake is dependent upon the same relations between v_1 and v_2 regardless of whether one is dealing with the model or with its prototype.

The basis for item 6 in the "Summary of Conclusions" may, therefore, be briefly stated, (*a*) the angle and intensity of the downflow in the wake have been shown experimentally to be free from scale effects, and the downwash, if it occurs at all, will likewise be free from them; (*b*) the ability of stack gas to escape the downflow in the wake depends upon experimentally derived relations between gas velocity and wind velocity, and each component in this relationship is shown to be free from scale effects by reference to well-established aerodynamic principles; (*c*) the homogeneous functional equation shows that temperature cannot enter the downwash relations as a direct variable; indirect temperature effects are shown experimentally to be small; (*d*) finally, the remodeled stacks behaved according to predictions.

R. H. Sherlock.[8]
E. A. Stalker.[8]

Hard-Facing Metals

COMMENT BY V. E. ALDEN[9]

For some time the writer has had an opportunity to observe a development in hard-facing practice which supports the Stellite experience so ably presented in this paper,[10] but in a somewhat different direction.

For many years it has been known that the cobalt-chromium-tungsten alloys have excellent resistance to wear under the most severe operating conditions, combined with relatively high temperatures. The inherently high cost of the cobalt-chromium-tungsten alloys has, however, served as an obstacle to their more general use.

There is the generally accepted opinion that the quality of "red hardness," inherent in the cobalt-chromium-tungsten alloys, imparts great resistance to abrasion at certain relatively high temperatures, and it has also been supposed that no iron-base alloy could have such resistance to wear.

An outstanding development of the last 4 years in the field of hard facing, however, has been the development of iron-base alloys, containing chiefly the relatively less costly constituents iron, chromium, nickel, molybdenum, and carbon. The wearing qualities of these alloys in the presence of temperatures up to at least 1350 F are equal or superior to those of the cobalt-chromium-tungsten alloys, made up of much more expensive constituents. This family of iron-base alloys goes under the name of "Coast Metals."

It is an interesting fact that this family of alloys, in an area not previously explored, was developed as a by-product of an investigation directed toward an entirely different objective.

This family of alloys has wearing qualities in the upper range of the group-3 classification, referred to by the author. Excellent service life has been obtained on such difficult and varied jobs as pug-mill knives and augers, steel-rolling-mill guides, coke-oven pusher shoes, and dies, in addition to wide use in the general crushing field.

Excellent control can be exercised over these iron-base alloys to give all sorts of interesting properties. Various coefficients of expansion are obtainable by slight modifications of the basic analysis and thus hard surfacing of cylindrical sections of all types of steels and irons can be guaranteed free from checks or cracks.

The writer would like to emphasize the point that substantial savings may be realized in many important instances by using a relatively inexpensive base metal and applying hard-facing materials to the wearing parts, rather than making the entire part out of the material, such as manganese steel, which is expected to take the severe wear.

An important point not clearly brought out by the author is that for many classes of equipment the maintenance of the original condition and original size of the wearing part results in the maintenance of original efficiency. Conversely, failure to maintain the original condition and original size may seriously impair operating efficiency. Those familiar with the extreme wear usually encountered in grinding and pulverizing equipment in a wide range of industries will appreciate this vital factor and its effect upon operating costs and, consequently, upon operating profits.

As one illustration of the savings due to increased service life, resulting from the use of hard-facing metals, an operator of a pulverizing mill recently informed the writer that each shutdown for replacing worn parts caused a loss, due to the interruption of the cycle of operations, of $60. Obviously, the use of a material which reduces the frequency of the shutdown periods by 80 per cent or more, is a most important factor. This is only one of the many illustrations which those familiar with the use of hard-facing materials could give of the savings effected as a result of greatly increased continuity of operations.

The writer would like to endorse the author's statement that laboratory tests of hardness and wear resistance are of relatively slight importance in evaluating the probable performance of hard-facing materials. Experience has shown that resistance to filing or grinding is usually more reliable as a means of giving preliminary indication of relative wear in this class of material. Wear in actual service, however, is the acid test. Toughness of the matrix is as important as extreme hardness, and this is particularly important if the wearing parts are subjected to impact.

One respect in which the experience with these iron-base hard-facing alloys differs from the experience outlined for the cobalt-chromium-tungsten alloys is that a majority of the applications have been made by arc welding. The widespread use and availability, and increasing acceptance of arc-welding methods, combined with the growing number of efficient operators of electric-arc-welding equipment, make advantageous the use of alloys which can be applied by arc welding. There are, however, a limited number of applications, such as the hard facing of the cutting edges of shears and dies where Coast Metals can usually be best applied by gas.

COMMENT L. W. WALLACE[11] AND E. R. SEABLOOM[12]

Hard facing is continually aiding the

[8] University of Michigan, Ann Arbor, Mich.
[9] J. H. Manning & Company, Chicago, Ill. Mem. A.S.M.E.
[10] "Hard Facing—a Process for the Mechanical Engineer," by E. E. Le Van, MECHANICAL ENGINEERING, June, 1940, pp. 459–464.
[11] Director, Engineering and Research Division, Crane Company, Chicago, Ill. Mem. A.S.M.E.
[12] Supervising Engineer, Research and Development Laboratories, Crane Company, Chicago, Ill.

engineer in solving baffling problems in design and reliable operation of metal structures. The writers' company has employed deposited surfacing alloys for several years, particularly on seating faces of valves used in high-pressure high-temperature services.

Hard-facing alloys, such as Stellite, serve the valve industry admirably because they possess excellent resistance to erosion, corrosion, abrasion, and withstand heavy loading at elevated temperatures without seizing or galling. Furthermore, they are quite readily applied to various base metals and offer a fair degree of machinability when proper cutting tools and grinding equipment are used.

To obtain the most satisfactory results, the following factors have to be taken into consideration: Design of parts to receive hard facing, establishing proper procedures in depositing the overlay materials, which includes training of welding operators, using sufficiently high preheating temperatures, and determining the correct cooling rates. The latter is very important especially when dealing with alloy-base metals which display suppressed transformations upon cooling. Unless this is followed, cracking of the deposited metal is apt to occur. By careful design, the cost of materials and labor involved may be materially reduced and, at the same time, improved results obtained. Proper equipment for carrying out the necessary procedures in hard-facing technique is, of course, also essential to the fabrication of reliable and quality products. The writer wishes to express the thought that satisfactory and economic results cannot be obtained unless a high degree of intelligence prevails in applying the hard-facing process.

AUTHOR'S COMMENT

In the discussion of the paper, emphasis has been placed on iron-base hard-facing alloys. There are many such alloys on the market, among them "Hascrome" rod and "Haynes Stellite" 93 rod, both of which are iron-base hard-facing materials and both of which have many excellent applications. These were both mentioned in the paper, typifying groups 1 and 2, respectively. Hascrome rod has been on the market for more than 10 years, as have other iron-base hard-facing materials.

The matter of maintaining the original efficiency of a mechanical part is, indeed, an important one. In many of the examples cited in the paper, the maintenance of original or near-original operating efficiency for long periods is a real saving accomplished by hard facing. For instance, the fact that bits used for drilling oil wells operate at nearly their original efficiency for such a long period has resulted in the use of only 14 bits today to do the drilling which formerly required 80, not so faced. This means a great many hours and dollars are being saved, because in the example cited, 66 "round trips" of the drill string to change drill bits are eliminated. This represents a substantial cost reduction.

The saving in power consumption for undercutting coal was also shown to be from 22 to 27 per cent through the use of hard-faced bits, which stayed sharp longer than ordinary bits, enabling the machine to cut more easily because of the maintenance of higher cutting efficiency by the hard-faced bits.

Steam valves which are hard-faced remain leakproof for much longer periods than unfaced valves, and here again the great savings made by hard-faced valves are due to maintenance of original operating efficiency over long periods of time. The same applies to other types of valves mentioned, such as those for automotive, aircraft, and Diesel engines. Maintenance of high operating efficiency of hard-faced exhaust valves in such engines is responsible for the lowering of operating costs as brought out in the paper.

Many other outstanding examples of savings made due to maintenance of original efficiency by hard-faced parts could have been cited, had space and time permitted. To give one more example,[13] the following performance record is cited:

GRINDER RINGS

(Life ratio 18 to 1)

	Steel ring	Stellited ring
Life per ring, hr	400	7500
Cost per ring	$135	$850
Repairs	..	$200
Total ring cost (7500 hr)	$2531.25	$1050
Time shut down for replacement and repairs, hr	427	30
Average bbl per hr	125	147
Cost of ring per bbl	0.022¢	0.0095¢
Increase in output, per cent	....	17

NOTE: The figures shown in the table demonstrate the savings that a prominent Midwestern Portland-cement company has effected with stellited grinder rings. The data in the table show the ring cost and output over a period of time equal to the life of the hard-faced ring, 7500 hr.

From the table, it will be noted that the average output was only 125 bbl per hr for the plain steel ring, whereas, it was 147 bbl per hr for the hard-faced ring. This substantial increase in grinding efficiency is typical of results obtained from hard-faced parts.

In the same book[14] the following also appears:

> A New York Company has standardized on stellited grinder rings not only because of their longer life but also because of the more efficient service rendered. An ordinary steel ring after 200 hr of service has dropped in efficiency to such an extent that production loss in barrels per hour is estimated at 20 to 30 per cent of the original. When the ring is finally removed, it is estimated that it is giving only about 70 per cent efficiency. The efficiency of a stellited ring, however, is not impaired till all the hard-facing alloy is worn off. Moreover, the cement particle size remains constant, whereas with a plain steel ring it increases. Another advantage of hard-faced rings is that the rolls last longer when working against a stellited-ring surface.

While the property of red hardness is believed to be important in connection with abrasion resistance, it is probable that this property alone does not entirely account for the excellent wearing qualities of the nonferrous cobalt-chromium-tungsten alloys. The combination of other properties, such as low coefficient of friction and extremely high resistance to corrosion, may be responsible. A nonferrous cobalt-chromium-tungsten-alloy surface retains its original finish under severe conditions, without the formation of a film of oxides or corrosion products which would be removed by the abrasion of a contacting surface.

It was brought out both in the paper and in the discussion that laboratory tests for comparative wear resistance of metals have not been particularly successful in predicting comparative wear under actual operating conditions. Likewise, resistance to filing or grinding has not been found to be an authentic indicator. In filing, the human element is too variable, as are the pressures used, the sharpness of the file used, and the temperature generated by varying amounts of friction, as a result of variation in the filing pressure and speed. In grinding, the type of wheel, its speed, its presentation to the work, and the pressure are subject to wide variations, and the tendency of a material to glaze the wheel surface by dulling the sharp particles in the wheel varies with varying compositions of alloys. This glazing effect in turn varies the heat generated at the surface, and this results in different temperatures at the point of contact. It has been demonstrated rather conclusively over a number of years that the only real test is a performance test under

[13] "Hard-Facing With Haynes Stellite Products," Haynes Stellite Company, New York, N. Y., 1939, p. 31.

[14] Reference (5), p. 32.

actual operating conditions of the part in question.

Many applications of the cobalt-chromium-tungsten alloys are made by the electric-arc process, as for example, cement-clinker-grinder rings, dipper teeth for steam and electric shovels, chemical mixer arms, coke-oven pusher shoes, excavating-bucket lips and dredging-cutter blades, and a host of other parts.

Discussion of the paper by Messrs. Wallace and Seabloom has pointed to the necessity for properly engineering hard-facing applications. These comments are, indeed, pertinent and deserving of careful consideration. Since the first pioneering efforts in the hard-facing field with Haynes Stellite rod in 1922, much has been learned about base metals, design of parts for hard-facing, preheating and cooling practices, and finishing procedures. With the large variety of parts hard-faced nowadays and the large variety of hard-facing materials available, as pointed out in the paper, and with many different kinds of base metal available, hard-facing applications are worthy of careful consideration by the mechanical engineer. The use of properly designed preheating and cooling equipment and jigs for holding the work has resulted in improving the quality and uniformity of hard-faced products. Engineering service along these lines has paid excellent dividends in broadening the hard-facing field and in giving complete satisfaction to users of hard-faced products.

E. E. LE VAN.[15]

Power and Velocity Developed in Manual Work

COMMENT BY I. K. FOSTER[16]

The authors of this paper[17] have undertaken to gather information of decided value in the measurement of manual work in industry. Studies made to determine the more efficient application of physical energy seem to indicate some interesting conclusions:

1 The motion of pull of the right arm toward the body permits the maximum horsepower to be applied; and within the shortest period of time. This appears to coincide with the natural tendency of most workmen and, fortunately, is most often desirable, due to other factors attendant upon the arrangement of a work station.

2 For the weights used in this test, a variation in weight did not seem appreciably to affect the productive horsepower developed. However, since parts and tools handled in our industry average considerably less weight, it would be interesting to see this curve extended into the lower weight scale.

3 Of further interest was the consistency of the comparative performance of subjects. Almost the same relationship was found between maximum horsepowers developed by the various subjects, regardless of weight or motion. This seems to hold true, but to a slightly lesser degree, for maximum velocities developed. The authors, in this experiment, found no definite relationship between physical characteristics and maximum horsepower developed.

Practical observation seems to indicate that, beyond outstanding physical characteristics, the employee's ability is more often determined by his mental and nervous make-up, and we would suggest that further investigations consider these factors.

The authors have devised a novel and thorough method of manual-effort measurement. As they mentioned, it was considered advisable to study individual elemental motions in order to eliminate uncontrolled variables found in more complex industrial operations. Free movements, without definitely controlled stopping points, were studied. However, this normally represents a small proportion of motions used in industrial operations. Controlled motions, requiring definite stops and positioning of tools and parts, would seem to be in the majority.

However, these studies were based upon maximum acceleration of weights. Further data on the power and velocity under actual average working conditions might prove of greater practical value. Also, if the experimental method could be simplified, this might permit more subjects and a greater variety of motions to be studied.

The authors have indicated their interest in investigations which will benefit industrial practices. Related subjects might be energy consumption requirements and fatigue; comparison between sitting- and standing-work stations; and the comparison of time and fatigue for single-handed versus two-handed operations, both with and without necessary eye-movement guidance to control hand movements.

Results of this experiment, while not conclusive, indicate that the ingenuity and thoroughness displayed by the authors should be applied to further studies in this field.

COMMENT BY GEORGE M. BUNKER[18] AND C. E. STRYKER[18]

It is hoped that additional information may be developed by the authors, which will enable the methods engineer to obtain the greatest output in useful work done with a minimum of fatigue to the operators.

As a suggestion for further investigation, reference is made to the statement by the authors that a primary concern of the methods engineer is the most effective application of human energy to the performance of useful work. In this the writers heartily agree but call attention to the fact that the studies thus far made relate to power rather than to energy. In mechanical devices as well as in the human body, the power developed has no direct relation either to the total amount of sustained energy which can be provided or the efficiency of developing this energy.

Therefore, it would seem to be desirable to conduct similar experiments with a steady level of work over a reasonable period, at the same time measuring the energy output and the thermodynamic efficiency of the body. It would be necessary to correlate these experiments properly with the physical condition and training of the individuals in the performance of the operations under study. It is well known that a trained athlete can perform a task with much less expenditure of energy than an untrained person; and the same thing holds true with respect to manufacturing and other labor operations.

Another point which must be considered is that it is necessary in any manufacturing operations to arrange them so that excessive fatigue will not result. To the best of the writers' knowledge there is, as yet, no satisfactory method of measuring fatigue, and we cannot, therefore, say just how the problem of fatigue may be correlated with the measurement of energy output and efficiency. Certainly, there is very great need for cooperative effort between motion-study engineers and physiologists.

COMMENT BY M. S. VITELES[19]

The investigation described in this paper is of especial value to methods engineers who are interested not only in solving immediate problems in a particular plant, but also in obtaining in-

[15] Haynes Stellite Company, Kokomo, Ind.
[16] Minneapolis-Honeywell Regulator Company, Minneapolis, Minn.
[17] "Power and Velocity Developed in Manual Work," by C. A. Koepke and L. S. Whitson, MECHANICAL ENGINEERING, May, 1940, pp. 383–389.
[18] McKinsey, Kearney & Company, Chicago, Ill.
[19] Professor of Psychology, University of Pennsylvania, Philadelphia, Pa.

formation concerning basic principles underlying human work activity. Far too few research projects in time-and-motion study satisfy both of these criteria.

Under controlled laboratory conditions, valuable data have been obtained concerning the effect upon velocity of motions and power expended, of variations in type of motion, weight of article moved, and individual differences in the worker. Both the methods employed and the results obtained warrant careful consideration by methods engineers.

A significant feature of the method is that it applies the principles of mechanical measurement to the human machine. By a clever determination of the maximum instantaneous horsepower required to move weights of varying amounts through differing motion paths, it presents data clearly understood by the engineer as well as by the industrial psychologist.

To the industrial psychologist, the most interesting of the many findings are the following:

1 The wide individual differences exhibited among even the few subjects used, Figs. 7 and 12 of the paper. The authors of the investigation recognize the importance of this fact for industrial selection. Of course, no final conclusions can be drawn from six cases, and it is hoped that subsequent research will be undertaken on this important variable.

2 The dependence of maximum horsepower and time to reach maximum velocity upon the type of motion used. It would seem from the discussion (although not clearly expressed) that the underlying variable is the speed with which the motion can be increased to its maximum, i.e., the rate of acceleration. Differences in maximum horsepower among types of motions appear to be related to the differences in time to attain maximum velocity rather than to the weight of the objects handled. Likewise, the velocity ultimately attained varies little with respect to type of motion, while the time to reach the maximum is dependent upon the type.

In this connection the writer is reminded of the investigations on types of movements by Professor R. H. Stetson, of Oberlin College, and his students.[20] Stetson emphasizes the desirability, especially in the case of rapid movements, of what he terms "ballistic movements," characterized by a sharp initial contraction of muscles and an optimal utilization of the developed momentum to continue the movement. The total amount of muscular effort of this type appears to be considerably less than that expended in a movement requiring continuous contraction of antagonistic muscles.

The setup in the present research seems quite conducive to the production of the "ballistic" type of movement since no definite terminal points were prescribed. The results thus can be related to investigations on ballistic movements. As such, the research indicates that, within the general class of ballistic movements, differences occur according to the pattern of muscle groups involved; e.g., the straight pull toward the body requiring the least time to reach maximum velocity.

The experiment not only furnishes valuable information but suggests further questions which need to be answered in future studies. For example, what were the physical characteristics of subjects *A* and *F*, who, from inspection of Fig. 7 of the paper, seem to exhibit the greatest variation in horsepower for the different types of motion? And, since many industrial operations require handling of light objects, what will be the results of extending the investigation to include weights down to a few ounces?

A question may also be raised as to the significance of the observed differences among subjects. Fractionation of the data has shown consistency in the differences, but further evidence obtained through the use of more cases is desired.

The experiment, of course, gives information only as to the maximum power expended at a single moment during the movement. It would also be of interest to determine the total amount of work done during the entire movement.

As suggested in the first paragraph of this comment, this investigation is of primary importance in its attempt to provide data on the basic principles underlying human work activity. With further investigations of this type, including those by Professor Barnes,[21] of the University of Iowa, the goal of the methods engineer, i.e., "the attainment of maximum output for the amount of energy expended," as given by the authors, will be approached more rapidly.

AUTHORS' COMMENT

Mr. Foster's discussion brings out many pertinent points in relation to the practical application of the results of this investigation. He also suggests several additional questions which were outside the scope of this study, but which should be made the object of future research. The authors have incorporated these suggestions in a long-range program of motion-study research.

Comparison of the energy requirements of sitting compared to standing work, of single versus two-handed work, and of controlled versus free or uncontrolled motions are all studies which would be of direct practical value to methods engineers. These relationships would lend themselves quite readily to research investigation.

Extension of present studies to include lighter weights, as suggested by both Mr. Foster and Professor Viteles, might bring out additional relationships, and such an extension is being planned. The effect of visual control of hand motions on the power and velocity of the hand is an important question in operations requiring accurate positioning of parts.

The effect of mental and nervous factors on the performance of manual work is a pertinent question, but one which appears to be rather intangible and difficult to investigate. Many of these mental factors are not well recognized and defined to say nothing of being capable of measurement. This might however be developed into a joint project between fields of engineering and psychology or psychiatry. A further attempt will be made in future studies, however, to correlate the results with the physical measurements of the subjects.

Messrs. Bunker and Stryker state, "the (maximum) power developed has no direct relation either to the total amount of sustained energy which can be provided or the efficiency of developing this energy." In the absence of experimental data to support this statement, the authors would be inclined to question it. It is true, there is no experimental evidence of such a relationship, but it seems logical that a person who, because of superior muscular development is capable of developing a greater instantaneous power, would also be able to maintain a higher level of sustained energy output. Both maximum power and sustained-energy capacity appear to be basically related to muscular development, hence, they must be related to each other. This relationship, or the lack of it, should be definitely established through further research.

In regard to muscular efficiency, the authors have been informed by Dr. Ancel Keys, Professor of Physiology, University of Minnesota, that all normal individuals in good health have about

[20] "Contrasting Approaches to the Analysis of Skilled Movements, by L. D. Hartson," *The Journal of General Psychology*, vol. 20, April, 1939, pp. 263–293.

[21] On the general subject of "Hand-Motion Studies," by R. M. Barnes and collaborators, University of Iowa, Studies in Engineering Bulletins, no. 6, 1936; no. 12, 1938; no. 16, 1939; no. 17, 1939; no. 21, 1940.

the same muscular efficiency regardless of their state of muscular development. Differences in the efficiency of the muscles result from disease or impairment of the muscular tissue, such as partial paralysis, deposits of calcium, or excessive fatty tissue in the muscles. Physiologists have determined that the normal efficiency of the muscles is about 38 per cent.

Another factor in the efficiency of muscular tissue has been found to be the speed of contraction of the muscle. The faster the muscle contracts, the less external work is done per unit of food energy supplied. Fig. 1 of this comment

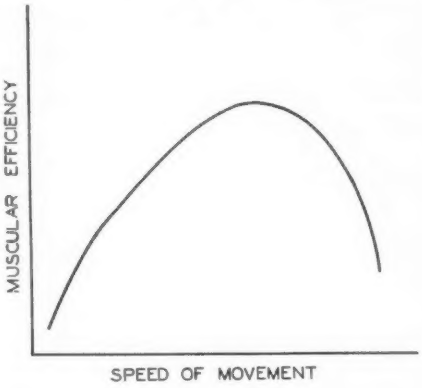


FIG. 1 RELATIONSHIP BETWEEN MUSCULAR EFFICIENCY AND SPEED OF MOVEMENT

shows graphically the general relationship between speed of movement and muscular efficiency. The decline of efficiency beyond the optimum speed is due to a property known to physiologists as "viscosity of the muscle."[22]

The common belief cited by Messrs. Bunker and Stryker that a trained athlete can perform a task with less expenditure of energy than an untrained individual has not been substantiated by physiological investigation, according to Dr. Keys. He states that the greater apparent ease with which a trained athlete performs is due to his greater muscular development and reserve of energy rather than to a higher efficiency which would enable him to perform the task with less energy.

A mechanical analogy of this might be found in comparing the hill-climbing performance of an 85-hp automobile with that of a 40-hp machine. If the two cars have the same weight, the total energy required to lift each of them up the hill will be the same. However, the higher-powered machine will climb with less apparent effort simply because of its greater reserve of power. Similarly the more muscular individual appears to use less effort in performing a given task simply because he has more reserve muscle tissue, not because he uses less energy.

Differences in the methods used on industrial operations, of course, will result in corresponding differences in the energy required. If the term "trained," as used in this connection implies the use of a better method, the statement that the trained individual can perform a given task with less energy is true. If, however, training refers to the general physical condition or muscular development rather than to the method used, the statement does not hold. Two normal persons having different degrees of muscular development but using the same method for a particular task will use the same amount of energy.

Professor Viteles emphasizes the importance of individual differences in the results and suggests the use of more subjects in future studies to give more conclusive results and, if possible, to bring out definite correlations between the results obtained and the physical characteristics of the subjects. The authors recognize the need for a larger group of subjects, but were limited in this investigation by the amount of work involved in analyzing the data. A method is now being developed which will give similar results with less work and hence make it feasible to use more subjects.

An attempt was made to relate the results of the tests to certain physical measurements of the subjects, but no definite relationships were found; this may have been due to the small number of subjects used.

Professor Viteles' observation that the rate of acceleration is the underlying variable affecting the differences in maximum horsepower developed with different types of motion appears quite valid. Since maximum velocity was nearly constant for all types of motion, it is evident that the greater power developed with certain motions must have been due to a greater force being applied in accelerating the weights. This indicates that the fundamental reason for the greater power with certain motions might be traced to a mechanical advantage in the musculature which permits application of a greater force. Further research is contemplated to determine whether there is a definite relationship between horsepower developed and the static force that can be applied with certain muscles.

Professor Viteles suggests that the motions analyzed in this investigation are "ballistic," that is, that they involve

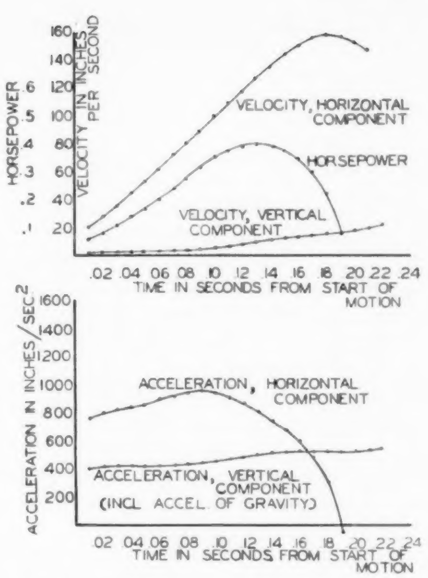


FIG. 2 VARIATION OF VELOCITY, ACCELERATION, AND HORSEPOWER THROUGHOUT TYPICAL TEST MOTION

a sudden muscular contraction at the start of motion and a follow-through, resulting from the momentum developed in the initial contraction. However, it should be pointed out that the time to attain maximum velocity averaged 0.21 sec after the start of the motion. This indicates that acceleration continued during the greater portion of the motion. This is also demonstrated in Fig. 2 of this comment, which shows the variation of velocity, acceleration, and horsepower throughout a typical test motion.

Since acceleration resulted from muscular force, this force must have been applied during a considerable portion of the motion and not merely for a short period at the beginning. If the test motion had fulfilled the common definition of ballistic motion, there would have been a much shorter period of acceleration, resulting in the attainment of maximum velocity very early in the motion. The velocity would have decreased gradually throughout the remainder of the motion as the momentum was spent.

It is true that the motions analyzed did not involve the opposing action of antagonistic muscles to control the path of motion and, in this sense, they do fall within the general classification of ballistic motions as distinguished from fixed or controlled motions. However, they do not fulfill the concept of a sharp initial contraction with motion continuing because of the developed momentum. At the start of motion, the force applied by the muscles increased sharply, but this force was maintained throughout the period of acceleration and not merely for an instant.

[22] "Human Physiology," by F. R. Winton and L. E. Bayliss, second edition, P. Blakiston's Son & Co., Inc., Philadelphia, Pa., 1935.

The authors question whether many motions, occurring either in industrial operations or in sports, actually do fulfill the complete definition of ballistic motions. Recently published stroboscopic photographs of golfers and tennis players indicate that the maximum velocity of the stroke is reached at approximately the point of impact with the ball. This also would indicate that the muscular force is applied for a considerably longer period than would be required for a single sharp contraction of the muscles.

Following Professor Viteles' suggestion, the authors have calculated from the original data the total work done and the average horsepower maintained up to the point of maximum velocity. A nearly constant ratio of 0.64 between the average and maximum horsepowers was found. This relationship was quite consistent for all weights handled and for all types of motion. Since average horsepower is related to maximum horsepower by a nearly constant ratio, the same pattern of relationships to weight, motion, and subject that were found for maximum horsepower will also apply to average horsepower.

The total work in foot-pounds done during the period of acceleration appears to be related to the type of motion used in about the same way as maximum horsepower. The total work done during the period of acceleration appears to be directly related to weight handled, i. e., the greater the weight, the greater the work done during the period of acceleration.

In conclusion, the authors wish to thank the discussers for their thorough analysis of the paper. We have received new ideas and many valuable suggestions for continuing the research.

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Mental and Social Waste

TO THE EDITOR:

In many professional or technical papers we continually find articles exhorting lawyers, doctors, and engineers to improve the use of the English language in their deliberations. Why should this be after the long years of studying and training? English would be the easiest language to learn and become the universal language if it were to be spelled phonetically, i.e., if the a, b, c's would correspond with the pronunciations in speech.

By actual count we find that over 90 per cent of the vowels, a, e, i, o, and u, are pronounced:

a—as in bar, tar, Panama
e—as in bell, president, electricity
i—as in bill, divisible, Mississippi
o—as in gold, port, Oklahoma
u—as in put, tune, student

If we would change the pronunciation of nonphonetical 5 to 10 per cent of the vowels to a phonetical method, as indicated, we would be compelled to spell only a few words and thereby spare our children at least a school year for the fruitless agony of spelling. This time can be used for better subjects and at the same time improve the language for everyone. This would not distort the English language. Derivation of words would be clearer. Literature and poetry would not suffer.

The spelling of the vowels of the alphabet as most letters are pronounced would coincide with the spelling in other languages, therefore it wou'd render the study of English a much easier task and also ease the study of foreign languages by English-speaking people. The dictionaries would become much simpler because it would not be required to decipher a pronunciation. Geographical and family names would be pronounced more uniformly and would not need to be spelled during costly telephone or radio conversations.

Speech and language is comparable to a machinery assembly line. Here the misfitting parts are corrected. In English we try to fit the good parts to the few bad ones by unphonetic spelling of the vowels of the alphabet, bringing about a confusion which costs the American nation alone over one billion dollars every year.

Many articles have been written endeavoring to make English spelling more correct, scientific, and easier to spell correctly, or better, to eliminate the necessity of spelling; also to remove the greatest barrier to Americanization of foreign population and the use of the English language as the international language.

The fault is not in the language but in the simple method of spelling the alphabet phonetically.

How do we compute the cost of one billion dollars per year for speech? First we must remember that executives or higher-priced men are usually the ones who dictate, phone, or telegraph and the time of two or more people is wasted in loss of time owing to spelling.

1 One minute lost per day by fifty million people, at one cent per minute, represents a yearly loss of $180,000,000.

2 Stenography and dictating amounts to at least $100,000,000.

3 Telephone and telegraph also claim at least $100,000,000.

4 Schools could devote at least a full school year for better subjects costing, for 2,000,000 pupils at $250 each, $500,-000,000.

5 The universal pronunciation of names would make foreign people feel more at home in English churches and would eliminate the desire for foreign-language churches and schools, promoting national and world unity and Americanization. The benefits are both moral and monetary.

6 Cost of printing and writing would be reduced by many millions of dollars.

The billion dollars is here, and there are many more benefits to mention, such as the more uniform thoughts, the enjoyment of more time and liberty to develop the great forces available in this wonderful universe, and more universal understanding and peace.

WERNER LEHMAN.[25]

[25] Consulting Engineer, Bucyrus-Erie Company, South Milwaukee, Wis. Mem. A.S.M.E.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval

after which it is issued to the inquirer and also published in MECHANICAL ENGINEERING.

Following is a record of the interpretations of this Committee formulated at the meeting of November 29, 1940, which were subsequently approved by the Council of The American Society of Mechanical Engineers.

CASE No. 732 (Reopened)

(*Special Ruling*)

Inquiry: May open-hearth process steel which meets A.S.T.M. Specifications A7-39 for Steel for Bridges and Plates, A10-39 for Mild Steel Plates, A78-39 for Steel Plates of Structural Quality for Forge Welding, and Specification S-53 for Boiler and Firebox Steel for Locomotives of a tensile strength of 55,000 to 65,000 lb per sq in., be used for Par. U-70 fusion-welded unfired pressure vessels having a shell thickness of less than $^1/_4$ in., provided it is of good weldable quality, the working stress does not exceed 5600 lb per sq in., and all other code requirements are met?

Reply: It is the opinion of the Committee that with the restrictions as stated in the inquiry, these materials may be used in the construction of Par. U-70 vessels.

CASE No. 870 (Reopened)

(*Special Ruling*)

Inquiry: Is it permissible in the construction of welded fire-tube boilers to insert into the cylindrical shell the tube sheets flanged outwardly and welded to the shell by a circumferential fillet weld which can be stress relieved but cannot be satisfactorily radiographed?

Reply: Since no adverse comment has been received on the proposed Par. P-115 as published in the September, 1940, issue of MECHANICAL ENGINEERING, it is the opinion of the Committee that fire-tube boilers may be constructed by inserting an outwardly flanged tube sheet in the shell, attaching it thereto by a circumferential fillet weld provided:

(1) The tube sheet is supported by braces or tubes, or both;

(2) The joint is wholly within the shell and forms no part thereof;

(3) The shell at the weld is not in contact with primary furnace gases;

(4) The throat of the full fillet weld is equal to 0.7 of the thickness of the head;

(5) The construction conforms in all other respects to code requirements including the type of welding, stress relieving, etc., but radiographing is not required;

(6) The construction is not used on the rear head of an h.r.t. boiler.

CASE No. 912

(*Interpretation of Par. U-66*)

Inquiry: Will not the intent of the Code with respect to separate name plates be met:

(1) If the manufacturer's name, the captions, and the data that are common to more than one vessel, excepting the Code symbol, are etched, cast, or impressed;

(2) If the Code symbol and other data which change with each vessel be stamped on the separate name plates prior to being affixed to the vessel;

(3) If the exact arrangement and size of letters of the required items do not exactly follow that of Fig. U-9 and Par. U-66(*a*).

Reply: It is the opinion of the Committee that:

(1) Separate name plates without the Code symbol and serial number may be prepared by etching, casting, or impressing;

(2) The Code symbol and all other required data may be stamped on the separate name plates prior to being affixed to the vessel, but the inspector shall see that the name plate with the correct stamping is applied to the proper vessel;

(3) Any arrangement of the required items may be followed except that the Code symbol must be on the left side of the plate. The height of the letters and figures on such a name plate shall be not less than $^5/_{32}$ in.

CASE No. 913

(*Revision of Pars. P-23 and P-24*)

Inquiry: In order to fill an urgent need, may the proposed revisions of Pars. P-23 and P-24 for steam and feedwater piping as published in the November, 1940, issue of MECHANICAL ENGINEERING be made effective immediately?

Reply: Since no adverse comment has been received and no changes are indicated in the proposed revisions of Pars. P-23 and P-24 as published, except that the lower limit of design pressure has been reduced from 125 lb to 100 lb, the revised[1] form of these paragraphs may be used in place of the present form pending the issuance of the customary schedule of revisions in the form of addenda sheets.

[1] See MECHANICAL ENGINEERING for November, 1940, page 832.

CASE No. 914

(*Interpretation of Par. U-66*)

Inquiry: When an unfired pressure vessel is a combination of chambers, one of which may operate at a pressure of less than 15 lb per sq in., but is combined with one or more other chambers operating at pressures above 15 lb, is it required that the chamber operating at the lesser pressure comply with Code requirements?

Reply: It is the opinion of the Committee that when an unfired pressure vessel unit consists of more than one pressure chamber operating at the same or different pressures, each such pressure chamber (vessel) which operates at a pressure above 15 lb per sq in. and would, by itself, be covered by the scope of the Code, shall be subject to the required inspections and hydrostatic test. Each such pressure chamber shall be stamped so as to indicate that the stampings apply only to the chamber (vessel) tested such as "jacket only," "stock space only," etc.

Any portion of the equipment that does not come within the scope of the Code does not necessarily have to comply with any of the Code requirements.

CASE No. 915

(*Interpretation of Par. P-274*)

Inquiry: When a boiler is fired only by blast furnace or other gas having a low heat value, how shall the safety valve relieving capacity be calculated?

Reply: It is the opinion of the Committee that when a boiler is fired only by a gas having a heat value not in excess of 200 Btu per cu ft, the minimum safety valve relieving capacity may be based on the values given for hand-fired boilers in the table accompanying Par. P-274.

CASE No. 916

(*Interpretation of Par. U-20*)

Inquiry: When pipe or tubes that comply with the specifications given in the Code are used in unfired pressure vessels as permitted by Par. U-13(*e*), what unit working stresses shall be used in calculating the allowable working pressures?

Reply: The unit working stresses to be used in the formulas for piping for calculating the maximum allowable working pressures of vessels made of material complying with the several specifications shall be as given in Table P-6.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

The Norris Project

The Norris Project. A Comprehensive Report on the Planning, Design, Construction, and Initial Operations of the Tennessee Valley Authority's First Water Control Project. Technical Report No. 1. Published by United States Government Printing Office, 1940. 840 pages, 319 illustrations, $1.50.

Reviewed by R. L. Daugherty[1]

THERE has been much dispute over the merits of various governmental projects and in all of it there has been room for an honest difference of opinion. But from what the reviewer of this book has seen of some of these public works, there can be no question of the excellence of the engineering work that has been done. Not only is this beyond reproach from the purely technical standpoint, but it is also beyond criticism from the economic standpoint. That is, granted that the project has to be put through, the government engineers concerned have seen to it that the most efficient and economical construction was employed.

The Norris project seems to be in this same category. The engineering profession is now indebted to the Tennessee Valley Authority for publishing this excellent volume, which makes available much information that is of value.

This treatise describes the project investigations made before starting any work, gives the details of the dam and powerhouse design, discusses access roads and employee housing, describes the construction plant and river diversion, and the dam and powerhouse construction, enumerates the reservoir activities, reports initial operation and related development, and ends with a complete discussion of the costs.

It is not only a good technical book, but it gives much space to the purely human side of the removal of families to new areas, and the sociological factors involved.

[1] Professor of Mechanical Engineering, California Institute of Technology, Pasadena, California. Fellow A.S.M.E.

Surface Finish

Friction and Surface Finish. Proceedings of the Special Summer Conferences at M.I.T., June 5–7, 1940. 244 pages, $8^1/_4$ × 11 in. Reproduced from typescript.

Reviewed by H. W. Gillett[2]

WHETHER or not he attended this highly successful conference, anyone interested in matters relating to mating surfaces will want these Proceedings to study at leisure. Theory starts by considering such surfaces as mathematically smooth, whereas actual surfaces are not smooth. The engineering implications due to deviation from smoothness were tackled at this conference. Measurement of evaluation of smoothness, in such fashion that a reasonably accurate description of the surface may be transmitted from one engineer to another, underlies any serious attack on the wider problem, so considerable attention was given to schemes of measurement and their limitations. Though one has to read the complete text, rather than only the particular papers dealing with that phase, to get all the angles, the whole text comprises the best existing appraisal of all those angles.

The sort of surfaces produced by various finishing methods, turning, grinding, lapping, honing, and "superfinishing" are discussed in terms of roughness, scratches, fuzz, and of the underlying cold-worked layer produced in varying degrees by various methods of finishing. As a corollary, the quantitative evaluation of abrasive stones was also discussed.

Finally (although scattered throughout the text) there was considered the effect of various degrees of perfection of finish upon wear, galling, seizure, dry friction, lubricated friction, bearing behavior and, sketchily, upon corrosion and fretting corrosion.

Naturally, lubrication, oiliness, and extreme-pressure lubricants entered the discussion as well. Not all of these topics were settled once and for all. Far more questions were raised than were answered, and it is this that makes the Proceedings so valuable, since the talks and the discussions are extremely thought-provoking. The informality of the meeting fostered the presentation of ideas and observations, often fragmentary, but worth following further, that would not have come out in more formal circumstances.

One can defy any mechanical engineer or metallurgist to read these Proceedings without getting new facts, new ideas, and much food for further thought. It's the sort of thing that will well bear rereading once a year.

[2] Battelle Memorial Institute, Columbus, Ohio.

Books Received in Library

A.S.T.M. Standards on Textile Materials, prepared by Committee D-13 on Textile Materials. October, 1940. American Society for Testing Materials, Philadelphia, Pa., 1940. Paper, 6 × 9 in., 368 pp., illus., diagrams, charts, tables, $2 (10 to 49 copies, $1.50 each). Sixty-six standards and tentative standards covering definitions and terms, methods of testing, and specifications for textile and related materials are presented in this compilation. Additional material appearing in appendixes includes photomicrographs of textile fibers, tables for yarn number conversion and relative humidity, a glossary of textile terms, proposed test methods, and abstracts of papers presented at committee meetings.

A T M (Archiv für technisches Messen). Lfg. 103, 104, 105, January, February, March, 1940. R. Oldenbourg, Munich and Berlin, Germany. Paper, $8^1/_2$ × 12 in., pp. T 1-36, F 1-2, illus., diagrams, charts, tables, 1.50 rm each. Three numbers of a monthly publication containing classified articles upon various types of apparatus and methods for technical measurements. Certain numbers also contain descriptions of specific instruments manufactured by German companies.

Aircraft Design, Two volumes. By C. H. L. Needham. Chemical Publishing Co., New York, N. Y., 1939. Cloth, $5^1/_2$ × 9 in., illus., diagrams, charts, tables; Vol. 1, 215 pp., $6; Vol. 2, 308 pp., $6.50. The general principles of aircraft design are presented both as a textbook and as a guide for the practical constructor. The first volume outlines in simple language the principles of flight and stability, control devices and the propeller, with a special chapter on parasite drag. The second deals mainly with the mathematical treatment of design, including materials, seaplane construction and experimental testing. The illustrative material is taken from British practice.

Aircraft Diesels. By P. H. Wilkinson. Pitman Publishing Corporation, New York, N. Y., and Chicago, Ill., 1940. Cloth,

$6 \times 9^1/_2$ in., 275 pp., illus., diagrams, charts, tables, $6. This book is devoted exclusively to the Diesel engine in aviation. It outlines the basic principles upon which the engine functions and the phases and processes involved. Fuel-injection equipment, superchargers, and accessories are described, the construction of different types of engines is presented in detail, and standardized pages of data are provided. The development and mass production of Diesels in Germany are discussed, their commercial utility is described, and suggestions are presented for the future.

AIRCRAFT ENGINES. Vol. 1. By A. W. Judge. D. Van Nostrand Co., Inc., New York, N. Y., 1940. Cloth, $5^1/_2 \times 9$ in., 380 pp., illus., diagrams, charts, tables, $5.50. In the words of its author, "the object of the present book, which is the first of two volumes on aircraft engines, is an endeavor to present the principles and results of relevant research work upon internal-combustion engines, for the benefit of those entering or already engaged in aircraft engineering work. It is also written to fill a gap existing in aeronautical literature, between the more advanced specialist books on theory and design and the elementary descriptive ones on aircraft engines, maintenance, etc." There is a bibliography.

BAUGHMAN'S AVIATION DICTIONARY AND REFERENCE GUIDE, Aero-Thesaurus. By H. E. Baughman. First edition, second printing. Aero Publishers, Inc., Glendale, Calif., 1940. Leather, cloth, $6 \times 9^1/_2$ in., 598 pp., illus., diagrams, charts, tables, $5. This reference book contains a wide variety of information frequently wanted by those engaged in aviation. An excellent dictionary of aeronautical terms is given, as are the regulations of the Civil Aeronautics Authority which concern students. The information upon occupations, drafting, lofting procedure, shop mechanics, and materials is extensive and practical. Flight maneuvers are illustrated by diagrams. There are tables of specifications and of needed mathematical data; directories of periodicals, house organs, publishers, clubs, societies, manufacturers, and schools, as well as many other data.

BILDWORT DEUTSCH Technische Sprachhefte 3. Starkstromtechnik. V.D.I. Verlag, Berlin, Germany, 1940. Paper, $6 \times 8^1/_2$ in., 36 pp., illus., diagrams, charts; paper, 1.50 rm; to members, 1.35 rm. Power-current technology is the subject of this third in a series of pamphlets designed to help engineers to read German technical publications. Various related topics are described and labeled, and illustrative diagrams are included as vocabulary aids. There is a large subject index.

GRAPHICAL TREATMENT OF VIBRATION AND AIRCRAFT ENGINE DAMPERS. By C. H. Powell. Bookcraft, Brooklyn, N. Y., 1940. Cloth, $6 \times 9^1/_2$ in., 288 pp., diagrams, charts, tables, $7.50. The first part of this text presents a concise method of graphical solution for complex vibrating systems, by geometrically combining the more easily obtained solutions of simple elemental systems. Part 2 is a more particular application of the methods developed in part 1 to various forms of engine dampers for torsional oscillation. Optimum conditions for all known types of dampers, the amplitude of the damper and the phase relations of the individual vibrating members are dealt with in detail. There are many charts and diagrams.

INDUSTRIAL MANAGEMENT. By R. H. Lansburgh and W. R. Spriegel. Third edition. John Wiley & Sons, Inc., New York, N. Y., 1940. Cloth, 6×9 in., 666 pp., illus., diagrams, charts, maps, tables, $4.50. General organization technique is stressed in this discussion of the principles, problems, ideals, and successful methods of industrial management. In the several chapters on fundamental considerations, the plant, the product, personnel, wage payment, managerial controls, and operating procedures, an effort has been made to show the relationships of each major portion of the business to the others and to outside influences. There is a bibliography.

INTRODUCTION TO ABSTRACT ALGEBRA. By C. C. MacDuffee. John Wiley & Sons, Inc., New York, N. Y., 1940. Cloth, 6×9 in., 303 pp., diagrams, charts, tables, $4. This book is planned for a full year's course, with problems furnishing laboratory material and concrete instances of the abstract concepts. The subject is developed logically from the system of rational integers to linear associative algebras. A selected body of facts from number theory, group theory, and formal algebra is offered, to provide a background for understanding and appreciating the generalized facts of abstract algebra.

PULP AND PAPERMAKING. Bibliography and United States Patents 1939, compiled by C. J. West. Technical Association of the Pulp and Paper Industry, New York, N. Y., 1940. Cloth, 6×9 in., 252 pp., $3. This comprehensive bibliography covers the articles upon pulp and papermaking which appeared during the year 1939 and the United States patents issued during that year which are of interest to the industry. Both sections are classified, the articles by a subject arrangement and the patents by the Patent Office classification. Subject and author indexes are included.

SALES ENGINEERING. By B. Lester. John Wiley & Sons, Inc., New York, N. Y., 1940. Cloth, $5^1/_2 \times 9$ in., 200 pp., diagrams, $2. Sales engineering is defined as the art of selling equipment and services which require engineering skill in their selection, application, and use. The author discusses the field of sales engineering, describes the work of the sales engineer under current conditions, and indicates the training and development of the sales engineer.

STEAM-TURBINE PRINCIPLES AND PRACTICE. By T. Croft, revised by S. A. Tucker. Second edition. McGraw-Hill Book Co., Inc., New York, N. Y., 1940. Cloth, $6 \times 8^1/_2$ in., 298 pp., illus., diagrams, charts, tables, $3. This book gives the operating engineer, the plant superintendent, and the manager the information necessary for the successful and economical selection and operation of steam turbines. It covers installation, lubrication, testing, and maintenance with special attention given to the economics of steam-turbine operation. The new edition has been generally revised to conform to current practice and has a new chapter describing the engineering principles involved in turbine selection and heat balance.

TILT OF THE AERIAL PHOTOGRAPH BY GRAPHICAL RESECTION. By R. O. Anderson, Chattanooga, Tenn., 1940. Paper, $5^1/_2 \times 8$ in., 50 pp., diagrams, charts, tables, $1. This pamphlet constitutes a supplement to the author's "Applied Photogrammetry." The contents consist of three new methods of computing the scale and tilt of the aerial photograph covering cases of excessive tilt and relief and also cases when the scale points fall upon a straight line. The latter condition causes failure in the Dropped-Perpendicular method as presented in "Applied Photogrammetry," to which this pamphlet is supplementary. The Graphical Resection method of tilt determination is effective for all positions of the scale points excepting, however, the condition of the three scale points coinciding. This method is treated in detail as it consists of several recently developed principles which differ widely from the Dropped-Perpendicular method. The other two methods; Residual Tilt and Oblique Calibrations are shown in Appendixes I and II.

TIME AND MOTION STUDY and Formulas for Wage Incentives. By S. M. Lowry, H. B. Maynard, and G. J. Stegemerten. Third edition. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1940. Cloth, $6 \times 9^1/_2$ in., 432 pp., illus., diagrams, charts, tables, $5. This textbook presents the principles and methods of making time and motion studies and constructing time formulas in such a way as to provide a practical guide for the factory executive. The organization and supervision of time-study, formula, and wage-payment work are outlined, with considerable emphasis on methods-study and leveling procedure, along which lines the present edition has been revised.

TREATISE ON ADVANCED CALCULUS. By P. Franklin. John Wiley & Sons, Inc., New York, N. Y., 1940. Cloth, 6×9 in., 595 pp., diagrams, charts, $6. Although the reader is assumed to be familiar with the fundamental methods of the calculus, these are briefly reviewed together with the prerequisite parts of algebra and analysis. The text then continues with an exposition of infinitesimal calculus, including those parts of the theory of functions of real and complex variables which form the logical basis of the infinitesimal analysis and its applications to geometry and physics. A group of exercises accompanies each chapter.

TURRET LATHE OPERATOR'S MANUAL. By J. R. Longstreet and W. K. Bailey; published by The Operators' Service Bureau of The Warner & Swasey Co., Cleveland, Ohio, 1940. Cloth, $7 \times 10^1/_2$ in., 240 pp., illus., diagrams, charts, tables, $2.50. This book, prepared by experienced engineers, provides an unusually comprehensive and detailed description of principles and practice. Tools and accessories, methods of working, short cuts, and special problems are discussed with the help of over 350 excellent illustrations and drawings. The book is designed expressly for the lathe operator.

VDI-FORSCHUNGSHEFT 401. Bemessung von Dampfstrahl-Verdichtern und ihr Verhalten bei wechselnden Betriebsbedingungen, by J. Wiegand. March-April, 1940; 24 pp. VDI-FORSCHUNGSHEFT 402. Wärmeleitung und Dampfdiffusion in feuchten Gütern, by O. Krischer and H. Rohnalter. May-June, 1940; 18 pp. VDI-Verlag, Berlin, Germany. Paper, 8×12 in., illus., diagrams, charts, tables, 5 rm each. The following subjects are discussed in these two German research publications: No. 401: Design of steam jet compressors and their behavior under varying operating conditions. No. 402: Heat conduction and steam diffusion in moist materials, with particular reference to porous conditions. A short list of references is included in each publication.

VIERSTELLIGE TAFELN UND GEGENTAFELN (Sammlung Göschen, Bd. 81). By H. Schubert, new edition by R. Haussner. Walter de Gruyter & Co., Berlin, Germany, 1940. Cloth, $4 \times 6^1/_2$ in., 181 pp., tables, 1.62 rm. The greater part of this small reference book is devoted to four-place tables of logarithms for numbers and trigonometrical functions, with provision for conversion in either direction. Additional tables are given for other mathematical operations. All logarithms are printed in a different color from other figures throughout the book.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Atlanta in the Springtime!

A.S.M.E. to Hold Spring Meeting at Atlanta, Ga., March 31–April 3, 1941

ATLANTA in the Springtime—magic words for the winter-weary! Remember them, for the A.S.M.E. Spring Meeting is scheduled for March 31 through April 3 at Atlanta, Ga., with headquarters at the Hotel Biltmore. While, of course, there will be excellent technical sessions to more than justify one's attendance, the thought of dogwood in full bloom, soft spring air, and golf courses in the pink of condition have their own particular pulling power.

Although Atlanta is not an industrial city, primarily, there are a number of large industrial plants in and about the city that will be of special interest to engineers. The Atlantic Steel Company specializes in a wide variety of light steel products. Chevrolet and Ford have assembly plants in operation. The main syrup plant of the Coca Cola Company as well as one of the largest bottling plants may be visited.

Special Day for Textile Engineers

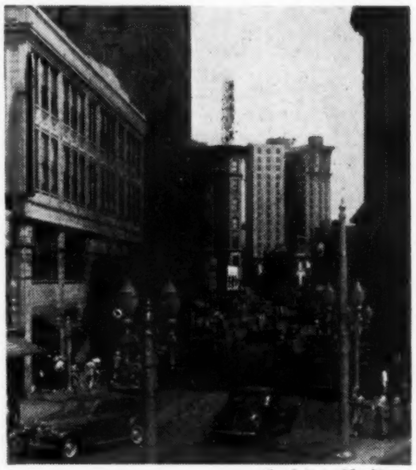
Of special interest to those in the textile field will be the Fulton Bag & Cotton Mills, one of the larger and best-run units of the South's principal industry. Textile-minded engineers are to be particularly well taken care of at this meeting for the Textile Division of the Society is arranging to stage, in conjunction with the Spring Meeting program, a full-day meeting, April 4, in Greenville, S. C., where the Southern Textile Exposition will be in full swing. Greenville is but a short trip from Atlanta and these extra textile sessions will round out the week perfectly.

Some of the Papers

Other Divisions of the Society are now busy gathering papers for sessions which they are to sponsor on fuels, heat-transfer, industrial marketing, materials handling, power, dust collecting, and vegetable oils.

Some of the papers—by no means a complete list—to be presented at these sessions include the following:

"Converting an Intermittent Tapping Wet Bottom Furnace Into a Continuous Tapping Furnace"



Cushing, N. Y.

PEACHTREE STREET—ATLANTA'S MOST FAMOUS STREET AND PRINCIPAL THOROUGHFARE

"Combustion of Four Fuels in One Boiler"
"Adaptation of Low-Grade Fuels to Combustion Equipment"
"Use of Refuse Coal as Pulverized Fuel"
"Design and Economics of the Watts Bar Steam Plant"
"Performance of Flat Plate Collectors of Solar Radiation"
"The Relation of Apprentice Training Programs to National Defense"
"Economics of Strip Mining With Portable Belt Conveyers (Clay Working)"
"Application of Emmet Mercury-Vapor Process to Existing Power Stations"
"Deep Water—1400-Lb Boiler Experiment"
"Study of Damper Characteristics"
"Separation of Liquid From Vapor, Using Cyclones"
"Mechanical Processes in the Production of Vegetable Oils"
"Efficiency in Cottonseed Oil Recovery"
"Continuous Solvent Extraction of Vegetable Oils"
"Linseed Oil Recovery"

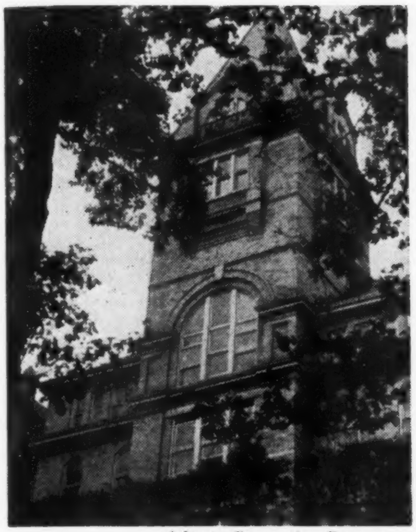
Cushing, N. Y.

THE GEORGIA STATE CAPITOL BUILDING AT ATLANTA, GA. STATUE OF GENERAL GORDON IN FOREGROUND

Georgia Tech in Atlanta

Atlanta, of course, is the seat of various educational institutions. Probably the most interesting of these to A.S.M.E. visitors will be Georgia School of Technology, whose campus is but four blocks from the Biltmore Hotel. An active A.S.M.E. Student Branch is a going part of Tech's undergraduate activities.

This city is also the headquarters for the Fourth Corps Area, executive offices of some of the largest defense projects now under construction in the country, including Fort Benning at Columbus—about a hundred miles away—the largest infantry training school in the world; several large mobilization camps throughout



Atlanta Convention Bureau

ADMINISTRATION BUILDING, GEORGIA SCHOOL OF TECHNOLOGY, ATLANTA, GA.

the State; and enormous air bases at Savannah, Ga., and Jackson, Fla.

There are today approximately 430,600 people in Atlanta, which is the center of a spiderweb of railroads embracing the Southeast as well as of a network of highways, bus and air-transport lines radiating in all directions. It is the third largest telegraphic center in the world.

"Musts" for Visitors

Places of interest, historic and otherwise, which should most certainly be included in a visitor's itinerary of the city include: Camp Gordon which is now being rebuilt for Army and Navy units and which was the camp where the famous 82nd Division trained for overseas service in the World War; Bobby Jones municipal golf course where the Battle of Peachtree was fought; Stone Mountain, which even without its unfinished carvings is one of the wonders of the World; Wren's Nest, the home of Joel Chandler Harris, "Uncle Remus" whose Br'er Rabbit and Tar Baby characters are well-beloved of all; the cyclorama painting of the Battle of Atlanta, the world's largest third-dimensional painting, a masterpiece depicting a scene from the Battle of Atlanta.

And no story of the attractions of Atlanta would be complete without mention of the famous Peachtree Street whose fame has echoed throughout the world. Lined with beautiful modern shops, it has become the fashion rendezvous of the South—a modern cosmopolitan shopping center.

Motor Routes

To interest those members who may wish to go to Atlanta by automobile, a route through the Great Smoky Mountains National Park is suggested: via Knoxville, Maryville (Aluminum Company of America), and Gatlinburg, Tenn.; thence Cherokee, Dillsboro, and Franklin, N. C., to Atlanta. Members with a little more time available might wish to return East via Savannah, Ga., and Charleston, S. C. The Cypress Gardens, the Magnolia Gardens, and others near Charleston should be in bloom then.

Index to Mechanical Engineering

As part two of the January, 1941, issue of the Transactions of the A.S.M.E., separate indexes to the Transactions and to Mechanical Engineering for 1940 were mailed to the A.S.M.E. membership.

An additional copy of the index to Mechanical Engineering may be secured from A.S.M.E. Headquarters, 29 West 39th Street, New York, N. Y., by sending ten cents for handling charges.

A.S.M.E. 1941 Management Conference to Stress National Defense

Philadelphia Section to Sponsor Meeting April 22–23 With Engineers' Club as Headquarters

The A.S.M.E. 1941 Management Conference in the interest of national defense will be held under the auspices of the Philadelphia Section of the Society on April 22 and 23, 1941, at the Engineers' Club, Philadelphia, Pa.

Organization and Waste-Control

A session will be devoted to organization with particular reference to its supervisory side, the multiple-shift problem, liaison with government contracting offices, and the coordination of subcontractors. At another session waste and scrap-metal control will be discussed when three or four well-known production engineers will tell what they are doing where the "spoiled-work" problem of learners is concerned and how full attention is given to the human elements involved.

Labor Relations to Be Discussed

Labor relations will be discussed from two points of view, that of dealing with grievances arising from increased defense tempo before they actually become serious; and that of handling relations with the labor organizations.

The production session of the Conference is to be based on the results of a questionnaire being mailed to the members of The American Society of Mechanical Engineers.

Arrangements are now being conducted to secure prominent speakers of national importance in the management field to speak at both luncheon and dinner meetings. The presentation of the Gantt Medal will also be made at the dinner although the name of its recipient has not been announced.

Management Division Members Will Be Kept Informed

Members of the A.S.M.E. Management Division will be kept informed on the progress of the Meeting while other members of the Society who are interested may obtain Conference information from headquarters upon request. The March issue of Mechanical Engineering will carry such further information as is available at press time.

R. L. Sackett to Be Active on A.S.M.E. Headquarters Staff During Absence of Secretary

During the absence on service in Washington with the Ordnance Department, of C. E. Davies, secretary of The American Society of Mechanical Engineers, Ernest Hartford, assistant secretary, will serve at headquarters as executive assistant secretary, and Dr. R. L. Sackett, dean emeritus of engineering, The State College of Pennsylvania, as assistant to the secretary. To Dr. Sackett have been assigned numerous duties in connection with joint activities customarily under the direct supervision of the secretary. He will also handle correspondence and interviews not directly and normally assigned to other staff members. During February Dr. Sackett will make an extended tour of local sections and student branches in the Southeast on behalf of the secretary.

Atlanta Convention Bureau

STONE MOUNTAIN—SIXTEEN MILES EAST OF ATLANTA, GA.

(This is the largest body of exposed granite on earth, its base is seven miles in circumference. The mountain rises 800 ft above the surrounding terrain.)

A.S.M.E. Nominating Committee Urges Members to Suggest Nominees for Office in 1942

Preferably Not Later Than April 1, 1941

THE 1941 Nominating Committee urges the members of the A.S.M.E. to give serious consideration to the selection of nominees for elective offices in 1942 and to submit their suggestions promptly, preferably not later than April 1, 1941.

The offices to be filled are President, four Vice-Presidents to serve two years, and three Managers to serve three years. The Constitution, By-Laws, and Rules of the Society, Articles C7, B7, and R7 govern the election of directors.

Forms Will Be Furnished by the Nominating Committee

It is not the duty of the Nominating Committee to solicit nominations, hence no communications will be sent out to Local Sections by the Nominating Committee. The procedure for suggesting nominees to the Committee is to write to the Secretary of the Nominating Committee to obtain the proper forms.

At its organization meeting in December, the Nominating Committee agreed to furnish forms for the convenience of those wishing to suggest nominees. This form contains spaces for most of the information which is essential to full consideration of each proposed nominee. Due to the fact that the Nominating Committee operates with only meager funds it is requested that eight copies of the form be turned in to the sectional representative on the Committee who will in turn see that each member of the Committee is properly informed. It is unnecessary to have additional forms for endorsers, but the Committee will welcome eight copies of a letter of endorsement from those wishing to support any suggested nominee.

This form when properly filled out presents a list of the activities of the proposed nominee within the Society as well as in other professional and nonprofessional organizations. The candidate's sponsor should also obtain preliminary assurance of willingness and freedom to serve if elected. National professional prominence and leadership are essential to able leadership of the Society. Knowledge of Society affairs and management obtained by previous service on committees is important in enabling the successful candidate to render service to the best of his real ability. The nominees for president and vice-presidents must be of the member or fellow grade; managers may be of any grade of membership.

Those who require additional information to complete the filling out of the Nominating form are invited to write to Ernest Hartford, assistant secretary, A.S.M.E., 29 West 39th St., New York, N. Y.

A. L. Kimball Elected Chairman

At the organization meeting of the 1941 Nominating Committee on December 5, 1940, A. L. Kimball was elected chairman, and N. C. Ebaugh was elected Secretary. The names of all of the members of the Nominating Committee, the Group they represent, and their addresses are given on this page.

The Committee decided to hold its final executive session during the Semi-Annual Meeting of the Society, June 16–20, 1941, at Kansas City, Missouri. On Tuesday, June 17th, of that week an open meeting will be held at which time it is hoped that any member of the Society who desires to appear personally before the Committee, to express his views or to discuss any matters pertaining to nominations, will do so. The hours of the Committee's opening meeting will be from 10:00 a.m. to 4:00 p.m. on Tuesday, June 17, 1941, at the Kansas City Headquarters.

Members' Desires Should Be Learned

It is highly desirable that representative regional groups make every effort to learn the desires of the membership in their region and convey those desires by mail or in person to the Committee through the regional representative.

The necessity of furnishing the Committee with 8 copies of the full and complete record of the proposed nominee before April 1 cannot be overemphasized.

The 1941 A.S.M.E. Nominating Committee

Group	Representative	Alternate
I	W. F. Thompson Westcott & Mapes, Inc. 139 Orange St. New Haven, Conn.	E. S. Dennison (1st) The Electric Boat Co., Groton, Conn. R. A. North (2nd) Farrel-Birmingham Co., Ansonia, Conn.
II	E. J. Billings Babcock & Wilcox Co., 85 Liberty St. New York, N. Y.	W. McC. McKee The M. W. Kellogg Co., 225 Broadway New York, N. Y.
III	A. L. Kimball General Engineering Department General Electric Company Schenectady, N. Y.	C. M. Merrick, 3rd (1st) Lafayette College Easton, Pa. S. T. Hart (2nd) Syracuse University Syracuse, N. Y.
IV	N. C. Ebaugh Mechanical Engineering Department University of Florida Gainesville, Fla.	C. E. Kerchner (1st) 23 W. 14th St., Denim Sta. Greensboro, N. C. H. S. Kent (2nd) 1909 Wellington Road Homewood, Md.
V	H. B. Joyce 616 Commerce Bldg. Erie, Pa.	C. J. Freund University of Detroit Detroit, Mich.
VI	R. E. Turner Power Plant Engineering 53 West Jackson Blvd. Chicago, Ill.	C. C. Wilcox (1st) Notre Dame University Notre Dame, Ind. C. A. Jacobson (2nd) 1107 Brewster Ave. Beloit, Wis.
VII	Earl Mendenhall Sterling Motors, Inc. 5401 Telegraph Road, Los Angeles, Calif.	H. L. Doolittle (1st) Southern California Edison Co., 601 W. 5th St. Los Angeles, Calif. W. H. Clapp (2nd) California Institute of Technology Pasadena, Calif.
VIII	L. J. Lassalle Louisiana State University University, La.	W. H. Carson (1st) College of Engineering University of Oklahoma Norman, Okla. A. L. Hill (2nd) 1033 Humboldt St. Denver, Colo.

Who's Who in Engineering Dead Line Feb. 15, 1941

ALL engineers who have not supplied data for the fifth edition of "Who's Who in Engineering," are urged to do so at once, as the dead line has been set at Feb. 15, 1941. It is hoped that all engineers meeting the general qualifications will be represented in the book.

The new edition is being revised under the editorship of Dr. W. S. Downs, with qualifications established by a committee of which Dean A. A. Potter, past-president A.S.M.E. is chairman, and on which serve as members the secretaries of national engineering societies.

Officers and Members of National Board of Woman's Auxiliary to A.S.M.E.

THE National Board of the Woman's Auxiliary to The American Society of Mechanical Engineers met at the headquarters of the Society in the Engineering Societies Building, New York, N. Y., on Thursday morning, January 9.

Officers and members of the Board are as follows:

President, Mrs. Frederick M. Gibson
First vice-president, Mrs. E. C. M. Stahl
Second vice-president, Mrs. A. R. Cullimore
Third vice-president, Mrs. Crosby Field
Fourth vice-president, Mrs. J. P. Harbeson, Jr.
Fifth vice-president, Mrs. J. H. Herron
Recording secretary, Mrs. C. H. Young
Corresponding secretary, Mrs. C. H. Fay
Treasurer, Mrs. A. H. Morgan
Assistant treasurer, Mrs. R. F. Gagg
Chairman of membership, Mrs. G. E. Hagemann
Chairman of local sections, Mrs. G. W. Farny
Chairman of courtesy, Mrs. C. W. Rice
Chairman of educational fund, Mrs. R. V. Wright
Chairman of Calvin Rice scholarship fund, Mrs. J. A. Brooks
Chairman of publicity, Mrs. A. R. Cullimore
Custodian, Miss Burtie Haar
Sponsor for Baltimore Section, Mrs. A. L. Kingsbury
Sponsor for Cleveland Section, Mrs. V. M. Frost
Sponsor for Los Angeles Section, Mrs. Crosby Field
Sponsor for Philadelphia Section, Mrs. G. L. Knight
Sponsor for Metropolitan Section, Mrs. Richard Austin

EDITH VA. CULLIMORE
Chairman, Publicity Committee

Lili Réthi, Artist Interpreter of Engineering Work, Exhibits in New York

DURING December, 1940, Miss Lili Réthi, whose drawing of the Engineering Societies Building in New York was used on the cover of MECHANICAL ENGINEERING for September, 1939, and whose sketches of the rooms of The American Society of Mechanical Engineers are familiar to A.S.M.E. members, exhibited her work at the Architectural League of New York. In addition to recent drawings of construction and architectural subjects done in this country, Miss Réthi exhibited several pencil drawings made in England and on the Continent. One of them is shown in the accompanying illustration.

Miss Réthi has been particularly successful in her handling of subjects of interest to engineers and architects, her drawings of construction work displaying a sense of human activity that makes some of the grotesque outlines of excavations and structures in process particularly appealing. Although the exhibition in December was the first public showing of Miss Réthi's work in this country, her work has been brought to the attention of engineers in Europe and Great Britain in their own gatherings at the headquarters of the Verein Deutscher Ingenieure in Berlin in 1931, at the World Power Conference in Stockholm, Sweden, in 1933, and at the Technical Museum at Vienna in 1934.

In England, among her other commissions, she made sketches for a booklet issued by the L.N.E.R., advertising posters for the L.M.S., featuring the Coronation train, for the G.P.O. underground railway, and of the rebuilding of the Waterloo station in London. One of her posters, a striking drawing of the Lillebaettsbro bridge in course of consruction for the Danish State Railways, was used at the opening of the bridge in 1935.

Miss Réthi is becoming known in engineering circles in this country not only through drawings that have appeared in MECHANICAL ENGINEERING and *Civil Engineering*, but also on the covers of several of the McGraw-Hill publications.

Diesel Cost and Performance Data Report Available

DIESEL engineers will find the 1939 Oil Engine Power Cost Report, just published, of considerably more value than previous issues. For in addition to stationary-plant coverage, it includes the first cost figures to be assembled and published on Diesel-powered vehicles of various types, and on a 5300-hp plant containing two oil-Diesel and one convertible engine operating on gas or oil on a Diesel cycle. A comprehensive review of the Report will be found on page 30 of the advertising section of this issue.

The Report is priced at $1.00 (80 cents to members) and obtainable from the A.S.M.E. Publication-Sales Department, 29 West 39th Street, New York, N. Y.

Washington, D. C., Section Welcomes Members to Its Meetings

MEMBERS of the Society whose work takes them regularly to Washington, D. C., or who, during the present emergency, are located there more or less permanently, are invited most cordially to send their Washington addresses to headquarters so that they may receive notices of the many important meetings being arranged by the Washington, D. C., Section. Men of prominence in government and national-defense work are being scheduled as speakers for the meetings during the coming months.

"Engineers Against Time"—Converting Peace Plants to War Work

Theme of Third A.S.M.E. National Defense Meeting, Cleveland, Ohio, March 12 and 13

HOW existing commercial plants, machines, and man power engaged in manufacture of peacetime goods can be adapted to the production of munitions for national defense in the race of "Engineers Against Time" is the theme of a two-day meeting of The American Society of Mechanical Engineers to be held at Cleveland, Ohio, March 12 and 13, with headquarters at the Hotel Statler.

Two previous meetings on production problems of national defense were attended by hundreds of manufacturers already engaged in munitions manufacture or about to enter upon it. These were more specifically devoted to shell manufacture, the first being held at Pittsburgh on September 11 and the second at Cincinnati on October 16 and 17.

Brief Practical Discussions to Be Presented

At both these meetings representatives of the Ordnance Department were in attendance to answer questions and participate in discussion. Formal papers, prepared with the object of publication in permanent form, were supplanted by briefer talks directed to the men who are actually faced with the problem of converting peacetime production to munitions manufacture and who are naturally more interested in knowing what is required of them, what steps to take to make the chips fly and speed up production, than in academic discussions of theory and design. Because of this fact the temper of the conferences can best be judged by the large attendance and the range and liveliness of the discussion. When the experts lay aside the prepared manuscript and talk freely and off the record in answer to direct inquiry from engineers who are right up against the production problem, the real value of these conferences is appreciated. It is this kind of atmosphere that is most helpful and it is naturally this kind of discussion that cannot be published.

Munitions Manufacture, Aircraft Production, Tanks, and Machine Guns on Program

The Cleveland meeting is being arranged as a result of the lessons learned at the previous conferences where it became evident what engineers were most concerned with. In addition to the always important subject of shell manufacture, the Cleveland meeting will have parallel sessions devoted to aircraft and tank production problems. Sponsorship of the third conference, therefore, is being enlarged to include not only the A.S.M.E. National Defense Committee, the Machine Shop Practice Division, and the Metals Engineering Divisions under whose auspices the previous conferences were planned and conducted, but the Aeronautic Division and the Committee on Education and Training for the Industries as well. As at Pittsburgh and Cincinnati, the meeting at Cleveland will be conducted jointly by the A.S.M.E. Local Section. The A.S.M.E. Cleveland Section has appointed a special committee of well-known engineers to take charge of local arrangements; and cooperation between the Cleveland Section and the professional divisions assures success to a timely and valuable opportunity for production men to get the benefit of expert discussion of their problems.

Adaptation of Existing Plant Challenge to Engineers

In adopting the general theme of adapting present commercial plant and skill to munitions production, the National Defense Committee has touched the practical aspect of the emergency problem—elimination of imagined bottlenecks and the spirit of discouragement that springs from lack of time to set up ideal and perfect manufacturing conditions. Much has been said about the inability to get new or specially designed machine tools, to build and equip plants with the sole object of producing munitions or aircraft, to find the skilled craftsman to produce the tools, jigs, and fixtures necessary for mass-production methods. The situation is a challenge to engineering ability to improvise where the ideal cannot be attained because of lack of time and experience in wartime production.

The A.S.M.E. accepts this challenge with confidence that engineers are able to adapt what plant, equipment, man power, and experience they possess to accomplish a vital emergency job. For this reason the Cleveland meeting is set up expressly for the thousands of manufacturers who are or soon will be engaged in production problems outside their peacetime routines. Certain essential items, like aircraft engines and explosives, can best be produced by the relatively few manufacturers who have long experience in the lines and who are now expanding old plants and constructing new ones. But in the manufacture of shell, tanks, and parts and accessories of aircraft literally thousands of plants to whom such work is novel will be engaged. It is with the object of helping engineers in such plants that the A.S.M.E. is planning the Cleveland meeting.

In addition to speakers and discussers from the Ordnance Department and Air Corps, engineers with wide experience in machining and metal cutting, surface finish, inspection, forging, press work, precision manufacture, personnel problems, and apprentice training will present papers covering the phases of skill, aircraft, and tank manufacture, and recruitment that form the bulk of the program.

Two-Day Program Provides Luncheon Speakers

Sessions will be held on the mornings and afternoons of Wednesday and Thursday, March 12 and 13. Two sessions will run in parallel throughout these days. On Wednesday these sessions will be devoted to aircraft and accessory production on the one hand and munitions manufacture on the other. On Thursday morning one session will have for its topic, tank manufacture; and at the other machine-gun production problems will be discussed, particularly with reference to the 20-mm machine gun. At the single session to be held on Thursday afternoon the subject will be training and recruitment of industrial personnel.

Further details of the program will be announced in the March issue of MECHANICAL ENGINEERING.

New Officers A.A.A.S. and Section M (Engineering) Elected at Philadelphia

"Charter of Democracy" Proposed

AT A slimly attended session of Section M (Engineering) of the American Association for the Advancement of Science, held at the Engineers' Club of Philadelphia, on December 31, 1940, in connection with the annual winter convention of the A.A.A.S., W. R. Woolrich, member of the A.S.M.E. Council, dean of engineering and director of engineering research, University of Texas, was nominated vice-president of the section to replace R. L. Sackett, dean emeritus, Pennsylvania State College. F. M. Feiker, dean of engineering, The George Washington University, Washington, D. C., was nominated to succeed himself in the office of secretary of Section M.

Discussion of the function and program of Section M, initiated by a communication from Dr. J. C. Hunsaker, vice-president A.S.M.E., head of the department of mechanical engineering, Massachusetts Institute of Technology, and retiring vice-president of Section M, resulted in a motion to refer the question to the representatives of the societies of which Section M is composed. The American Society of Mechanical Engineers is one of the bodies, and its representatives are R. F. Gagg and R. L. Sackett.

Dr. Hunsaker's communication suggested possible affiliation with the physicists in the A.A.A.S. as one way of meeting the problem of attendance at Section M meetings. In the discussion, however, it was pointed out that the interests of the societies comprising Section M were broader than the field of physics, and included mathematics and the economic sci-

ences as well, for which the A.A.A.S. also provides sections.

Resolution Proposes "Charter of Democracy"

At the meeting of the council of A.A.A.S., held during the Philadelphia convention, Dr. Irving Langmuir, 1934 Holley Medalist of the A.S.M.E., associate director of research, General Electric Laboratories, Schenectady, N. Y., was elected president to succeed Dr. Albert F. Blakeslee, of the Carnegie Institution of Washington. Dr. Langmuir will take office at the 1941 convention of the A.A.A.S. next December. The A.A.A.S. has a membership of 20,000 and has affiliated with it scientific and learned societies with memberships that total nearly a million.

The executive committee of the A.A.A.S. Council voted to adopt "in principle" a resolution calling for an attempt "to formulate, on scientific principles, an international charter of democracy." The resolution, which was presented by Prof. Richard M. Field, of Princeton University, was referred to a subcommittee composed of Dr. J. McKeen Cattell, chairman of the executive committee; Dr. Forest Ray Moulton, permanent secretary, A.A.A.S.; Dr. Edwin G. Conklin, executive officer of the American Philosophical Society; and Dr. Henry B. Ward, of the University of Illinois.

Text of Resolution

The resolution, as revised by them, read as follows:

"Whereas, at this time of international stress, the American Association for the Advancement of Science, at its 106th meeting convening in Philadelphia, a city sacred to the foundation of our Republic, realizing the share of responsibility of scientific men for the general welfare of free peoples, seeks the cooperation of their English-speaking colleagues:

"Be it resolved, that the American Association for the Advancement of Science wants the cooperation of the British Association for the Advancement of Science in attempting to formulate, upon scientific principles, an international charter of democracy.

"Be it resolved, that a copy of this resolution be immediately cabled to the British Association for the Advancement of Science and sent to all presidents of the affiliated societies of this association and sent to the editor of Science for publication."

J. W. Barker Elected to Executive Committee

Dr. Joseph W. Barker, member A.S.M.E., dean of engineering at Columbia University, and Dr. Walter B. Cannon, of Harvard University, retiring president of the A.A.A.S., were elected members of the A.A.A.S. executive committee.

C. E. Davies Added to Sigma Xi Executive Committee

C. E. Davies, secretary A.S.M.E., was elected to the executive committee of Sigma Xi, national research honorary society which holds its meeting with A.A.A.S. Dr. James R. Angell, president-emeritus of Yale University and educational director of the National Broadcasting Company, and Prof. A. Elizabeth Adams, of Mount Holyoke College, were added to the Sigma Xi alumni committee.

A.S.M.E. Calendar
of Coming Meetings

March 12–13, 1941
National-Defense Meeting
Cleveland, Ohio

March 31–April 3, 1941
Spring Meeting
Atlanta, Ga.

April 3–4, 1941
Textile Division Meeting
Greenville, S. C.

April 22–23, 1941
National Management Conference on Defense
Philadelphia, Pa.

June 11–14, 1941
Oil and Gas Power Division
Kansas City, Mo.

June 16–20, 1941
Semi-Annual Meeting
Kansas City, Mo.

June 20–21, 1941
Applied Mechanics Division
University of Pennsylvania
Philadelphia, Pa.

October 12–15, 1941
Fall Meeting
Louisville, Ky.

Fall, 1941
Joint Meeting of A.S.M.E. Fuels and A.I.M.E. Coal Divisions
Lafayette College
Easton, Pa.

December 1–5, 1941
Annual Meeting
New York,
N. Y.

(*For coming meetings of other organizations see page 28 of the advertising section of this issue*)

Progress of A.S.M.E. Power Test Codes Reported at 1940 Annual Meeting

Main Power Test Codes Committee Meets

THE Power Test Code group of committee meetings during the 1940 A.S.M.E. Annual Meeting, began with a breakfast meeting on Tuesday morning, December 3, of Committee No. 6 on Steam Turbines, C. H. Berry, chairman. The present revision of this code has passed through the final editing step in the procedure so it will shortly be presented to the Council for approval.

On that same afternoon the main Committee on Power Test Codes held its annual meeting with forty-six members of the main committee and the technical committees present. Francis Hodgkinson was in the chair and many items of routine business were transacted. Thirteen of the technical committees presented reports.

8 Sections of Instruments and Apparatus Completed

W. A. Carter, chairman, stated that during the year his technical committee on instruments and apparatus had completed eight sections of its comprehensive supplementary reports. C. B. LePage, secretary to the committee, reported for the record that during the year good progress had been made in the revision of five test codes and two supplements. Progress also had been made toward the completion of the following four new projects: Test codes for gaseous fuels, pulverizers, dust-separating apparatus, and fans.

Earlier in the afternoon of this same day Technical Committee No. 1 on General Instructions, T. Baumeister, Jr., chairman, held a meeting and reviewed in detail a preliminary draft of the revision of General Instructions.

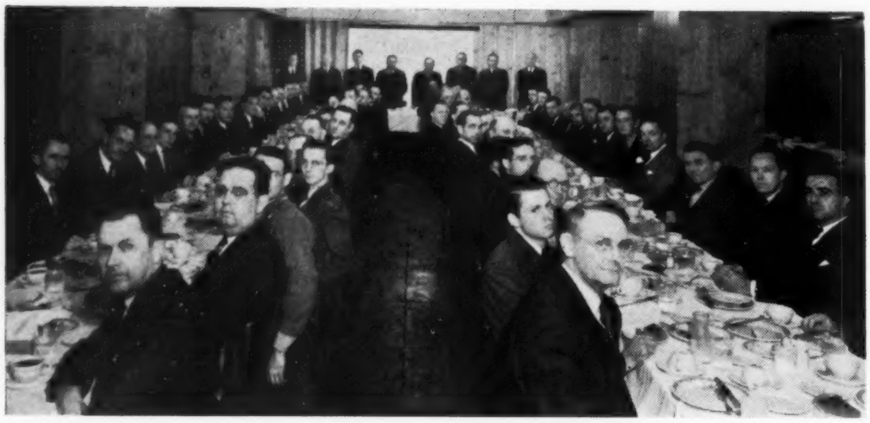
On Wednesday afternoon Technical Committee No. 13 on Refrigerating Systems, B. H. Jennings, chairman, held a meeting for consideration of (1) the final revision of the short form test code for reciprocating compressor systems; (2) the drafting of the code for centrifugal compressor systems; (3) preliminary plans and recommendations for the code which is to cover the testing of steam-jet systems; and (4) the general form and content of the main body of this revised test code.

The meeting of Technical Committee No. 17 on Internal-Combustion Engines, Lee Schneitter, chairman, was held on Wednesday morning December 4, with fourteen members of the committee and guests present. The special business of this meeting was the review of the November, 1940, draft of the proposed revision of the present A.S.M.E. test code for this type of prime mover.

On Wednesday afternoon Prof. C. R. Soderberg's Technical Committee No. 20 on Speed, Temperature, and Pressure Responsive Governors held its meeting.

Committee on Hydraulic Prime Movers Meets

On Friday morning, December 6, following the close of the Annual Meeting proper, Technical Committee No. 18 on Hydraulic Prime Movers, with S. Logan Kerr as chairman, held its annual meeting. Reports were received and discussed on the following methods of measuring water: (1) Cole pitometer method, (2) current-meter method, (3) pitot lock method, and (4) photoflow method.



MID-CONTINENT SECTION DINNER AND MEETING ON DECEMBER 9 ATTRACTS 86 MEMBERS AND GUESTS

(Those standing at the head table are left to right: M. R. Wise, secretary, C. P. Porter, T. C. Webb, E. E. DeBack, the speaker of the evening, E. C. Baker, chairman, H. R. Auerswald, C. O. Glasgow, treasurer, and D. K. Hutchcraft.)

National-Defense Projects Are Discussed at Meetings of Several A.S.M.E. Local Sections

WITH more and more emphasis being placed upon the National-Defense Program by the government, manufacturers, and labor, the Local Sections of The American Society of Mechanical Engineers are doing their bit in the various parts of the country by sponsoring local meetings dealing with the engineering phases of military aviation, ordnance, and machine-tool manufacture. During November and December, thousands of A.S.M.E. members and guests were present at these meetings.

A perusal of the following reports indicates some of the phases of National Defense which mechanical engineers are discussing today. Junior activities have lagged since so many Juniors have already been called into active service with the Army and Navy or are working overtime on defense projects.

Akron-Canton Section Hears Talk on "Superfinish"

At the Jan. 9 meeting of the Akron-Canton Section, 90 members and guests heard M. W. Petrie of the sales division of the Chrysler Corporation talk on the subject "Superfinish—The Preparation of Smooth Surfaces." Mr. Petrie compared and illustrated the surfaces obtained by turning, burnishing, grinding, honing, and superfinishing, explaining the advantages of the latter. Methods used to determine surface irregularities were also discussed. Mr. Petrie substituted ably for D. A. Wallace, also of Chrysler, who was unable to attend. An interesting discussion followed Mr. Petrie's talk.

Boston Section Holds Student Branch Night

THE meeting of Boston Section on Dec. 12 at Massachusetts Institute of Technology was dedicated to the A.S.M.E. Student Branches at Tufts College, Northeastern University, and M.I.T. At the usual premeeting dinner, the chairmen of the three student branches were guests of the Section. G. K. Saurwein, chairman of the Section, announced that a poll conducted by the various engineering societies in New England indicated that most engineers were in favor of registration for engineers and, consequently, a bill would be filed with the next Massachusetts legislature. He then introduced F. H. Rosencrants, vice-president in charge of engineering, Combustion Engineering Company, who discussed the boiler now under construction by his company for the Montaup Electric Company. The talk was illustrated with slides.

115 Attend Central Pennsylvania Meeting

Central Pennsylvania Section held its Nov. 26 meeting at Pennsylvania State College. Walter R. Sykes gave an illustrated lecture on the manufacture and application of fiberglass. The 115 members and guests took a great deal of interest in the exhibit of fiberglass products.

Power and Management Discussed in Chicago

At the Dec. 11 meeting, 36 members of Chicago Section listened to a paper on "Industrial Power Plants" presented by J. M. Lenone. He outlined the factors involved in the design of different types of industrial power plants, particularly the provisions which must be made for process steam.

H. M. Black, the energetic secretary of Chicago Section, reports that 85 members and guests were present at the management session on Dec. 13 which was voted the best yet held by the Section in that field. Lawrence A. Appley outlined the basic factors involved in any job of management. In conclusion, he showed how these factors can be applied through the use of management formulas.

Hundreds Present at Detroit Section Affairs

On Nov. 5, one hundred members and guests of Detroit Section enjoyed an inspection trip to the Oakman plant of the Ex-Cell-O Corporation where they saw the production of thread grinders and other machine tools. Following dinner, Carroll R. Alden, chief research engineer of the Corporation and member A.S.M.E., spoke on "Cooperation With National-Defense Industries," in which he discussed the relation of the tool industry to the National-Defense Program. Particularly interesting to all was the story how Alex Dow, past-president A.S.M.E. and Detroit District Ordnance Chief, and the corporation designed and perfected a new type of shell-turning machine.

The Dec. 18 meeting held in conjunction with the Engineering Society of Detroit featured a talk by Col. A. B. Black, U. S. Army, of Fort Knox, Ky., on army tactics as used by the American and the modern German armies.

Local Defense Program Discussed at Ft. Wayne

Members of Fort Wayne Section met on Dec. 4 to hear Capt. Clarence Cornish, manager, Fort Wayne Airport, summarize the progress in the negotiations between the city and the War Department in regard to the location of a $2,000,000 air base which is to be constructed in Fort Wayne within a few months. He also enlarged upon the steps necessary to adapt the city's airport for the future requirements of civil and military aviation.

Florida Learns About Modern Naval Aviation

The University of Florida was the scene of the Dec. 7 meeting of the Florida Section which had as guests the local chapter of the A.I.E.E. and the A.S.M.E. Student Branch at the University. Lieut. C. A. Pound, Jr., U. S. Naval Reserve, gave an outline of the various duties of the naval aviation force and the type of pilot training required to produce first-class pilots. Particularly interesting was his discussion of the functions of the various squadrons at the time of contact with the enemy.

Greenville Hears About Ordnance Developments

Lieut. Col. George W. Hirsch described to members of Greenville Section on Dec. 16 the recent developments in ordnance. Using slides to illustrate his paper, the colonel discussed the changes in weapons and armored equipment, the mobility of modern tactical units, and the part of the engineer in mechanized warfare.

100 at Los Angeles Meeting

The December 12 meeting of the Los Angeles Section had a splendid turnout of about 100

members and guests. The two speakers from the Firestone Tire & Rubber Co. were D. W. Anderson and H. M. Stilley. Mr. Anderson described the new bulletproof gasoline tanks developed in this country comparing them with those in use in Europe, and a new rubber which is capable of conducting electricity. This latter product will be utilized in airplane and gasoline-truck tires so that static electricity produced can be discharged into the ground. Mr. Stilley gave a short history of the tire industry and other recent developments including large-diameter tires for tractors and earth-moving machinery. The meeting was closed with the showing of motion pictures of the Indianapolis races.

Technic of Air Cleaning at Louisville Meeting

New developments in air cleaning were discussed at the Dec. 5 meeting of the Louisville Section by H. J. Noles. The differences between manual cleaning with mats and cleaning by means of electrically charged plates were brought out. Slides illustrated the various sizes of dust particles encountered in industrial air and the percentage removed by the various methods of cleaning.

Mid-Continent Section Features Recycling

After reports from various committees, the Dec. 9 meeting of Mid-Continent Section had a paper by E. E. DeBack, superintendent, Coastal Recycling Corp., on "High-Pressure Distillate Recovery and Recycling Operations in the South Texas Fields." Of interest to the 86 members and guests were the colored slides illustrating the applications of the equipment described by the speaker. According to Mr. DeBack, the principle of the method is the extraction of the "wet" fractions from the gas wells and the return of the gas to the original formation to maintain the pressure and to eliminate the possibility of retrograde condensation.

New Orleans Reports on Recent Activities

During the last four months, members of New Orleans Section have attended the many interesting and instructive meetings arranged by the Program Committee. The subjects discussed by speakers have included national defense, engineering employment, industrial production, and design. In December, members took part in an inspection through a Baton Rouge plant and in a joint meeting with the A.S.M.E. Student Branch of Louisiana State University. In January, the Section held several sessions in conjunction with the annual meeting of the Louisiana Engineering Society.

Philadelphia Session Held on Cutting Tools

More than 200 members and guests of Philadelphia Section attended the Dec. 10 meeting to listen to papers by M. F. Judkins on "Cutting-Tool Materials," and by W. H. Oldacre on "Cutting Fluids." After the showing of a motion-picture film on sintered carbides, the papers were discussed by Coleman Sellers and Frank Hamlet.

Symposium on Management by San Francisco Section

More than 60 members and guests of San Francisco Section were present on Dec. 5 for a symposium on management. Alexander R. Heron, director of industrial relations, Crown Zellerbach Corp., in his role of presiding officer did much to make the meeting a success with his remarks, both witty and serious. The framework of management was covered by Professor Holden, Stanford University, and the mechanics of management were discussed by Ben Warren, chief industrial engineer, Columbia Steel Corp. Interest of the audience in the subjects was attested by the lively discussion which followed the presentation of the papers.

Schenectady Meeting on Plastics Attracts 200

The largest meeting ever held by the Schenectady Section took place on Dec. 12. More than 200 members and guests were present to hear a talk by H. M. Richardson, plastics department, General Electric Company, on "Plastics," in which he discussed various types of plastics and their limitations and advantages.

137 Attend Toledo Session on Plastics

"What Is New in Plastics," was the title of the paper presented on Dec. 12 by Harold F. Stose, Owen-Illinois Plastics Division, before 137 members and guests of Toledo Section. The speaker traced the origin of plastics, their history, and modern manufacturing methods and applications. An extensive display of plastic products was shown. The program was concluded with a 40-minute color-sound movie produced by *Modern Plastics* magazine.

More Than One Hundred at Virginia Section Meeting

The Virginia Section held a joint meeting with the Central Virginia Engineers Club in Petersburg, Va., on Nov. 29. A total of 111 members and guests were in attendance at the meeting which was preceded by a social hour and dinner. G. C. Molleson, chairman of the Section, gave a short paper on "Neoprene." Following this, three sound motion pictures were exhibited, including "The Manufacture of Vacuum Tubes," "A New World Through Chemistry," and "The Story of Neoprene."

With the Student Branches

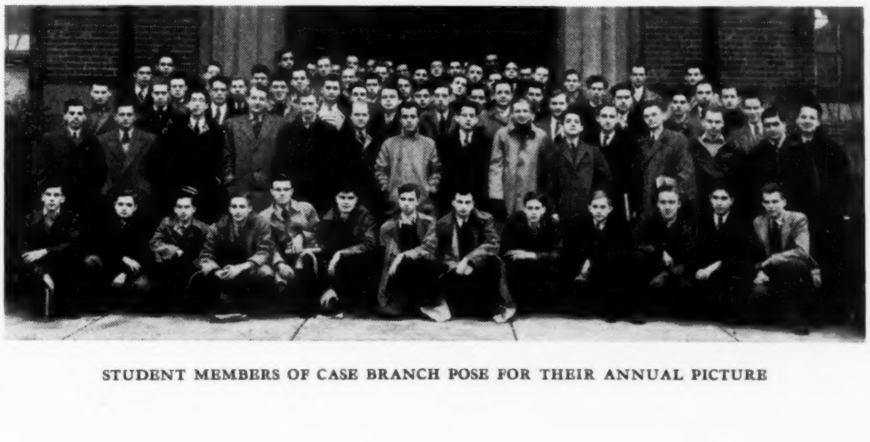
Headline Session at Akron Branch

SUPERSTITION had no place in the program of AKRON BRANCH at its Dec. 13 meeting. The headliner of the evening was A. D. Maclachlan, past-chairman of the Akron-Canton Section of the A.S.M.E., who discussed "The Employer Looks at You." In his talk, determination, courage, and loyalty were regarded as the attributes most necessary if a young man wants to succeed. The discussion that followed proved to be very interesting.

ARKANSAS BRANCH featured a paper at its Dec. 12 meeting by John McLeod, Taylor Instrument Co., on "Instrument Control." Several instruments were shown and demonstrated. Following the technical session, members and guests were served refreshments while a quartet of members sang Christmas carols.

BUCKNELL BRANCH at its Nov. 26 meeting showed a motion picture on the "Unionmelt" process of welding as used in the construction of tank cars.

CASE BRANCH keeps its treasury in the black by holding contests, such as radio raffles and treasure hunts. At the Dec. 11 meeting, R. M. Rush, Case '08, and manager of industrial department, Dravo Corporation, described the direct-fired unit heaters utilized at La Guardia Field at North Beach, N. Y.



STUDENT MEMBERS OF CASE BRANCH POSE FOR THEIR ANNUAL PICTURE

Eighty Attend Cincinnati Dinner

Eugene Feerer, vice-chairman of the CINCINNATI BRANCH, opened the dinner meeting on Dec. 3 by welcoming the eighty student members who were present. He then introduced Professor Joerger, honorary chairman, who addressed the group. Bruce Geiger, secretary, reports that the Branch has 114 members this year, the largest number in the history of the organization.

CLARKSON BRANCH members made an inspection trip on Dec. 11 to the Racquette River Paper Company, Unionville, N. Y. Since time was limited it was impossible to see all the phases of paper making, so only the "high spots" were covered.

COLORADO STATE BRANCH for Dec. 2 arranged a field trip to the local power plant. Twenty-four members spent three hours on the inspection. The last meeting of 1940 was held on Dec. 16. Through the courtesy of the American Telephone and Telegraph Company, John C. Flemming and L. Brown presented a series of sound motion pictures on wire drawing and on the audio tube.

COOPER UNION BRANCH (evening) presented a program on Nov. 28 which was of such interest that 120 members and guests came to the meeting. The speaker was W. W. Bishop, supervisor of engineering training, Wright Aeronautical Corp., and the subject was a description of the opportunities awaiting young engineers in the aeronautical industry.

Cooper Union Holds Christmas Dinner

The outstanding event in the year's program of COOPER UNION BRANCH (day) was the Christmas dinner on Dec. 21 with an attendance of 51 members and 20 guests. While the turkey together with its trimmings was being enjoyed, each alumnus present was introduced and asked to give a brief account of his work outside. After Dean George F. Bateman extended the season's greetings to all, Professor Lynch of the humanities department contributed to the cheerful atmosphere with his witty remarks. This was followed by the singing of Christmas carols and a bowling match between the students and the faculty.

CORNELL BRANCH presented a film, "The Magic of Modern Plastics," on Dec. 10 to an audience of 195. At this time it was announced that the school was inaugurating a

A PART OF THE FESTIVE GROUP PRESENT AT COOPER UNION BRANCH'S CHRISTMAS PARTY

MEMBERS OF THE STUDENT BRANCH AT THE MISSOURI SCHOOL OF MINES AND METALLURGY

course in engineering journalism beginning with the second term. This innovation is designed to give technical instruction both in editorial procedure and in business methods to members of the staff of *The Cornell Engineer*.

DREXEL BRANCH had John Latham, Millville Manufacturing Co., as the guest speaker on Dec. 5. His topic was "Power Plant Operation." He showed that it was cheaper to produce power than to buy it from an outside source.

Indoor Picnic at Idaho

The annual mechanical-engineer indoor picnic was held by IDAHO BRANCH on Nov. 27 in the laboratory. There was a turnout of 50 students to see the different laboratory appa ratus in operation. Following the demonstration of Diesel engines, steam engines, and gasoline engines, ice cream, cookies, and coffee were served.

ILLINOIS BRANCH conducted an "Information Please" program on Dec. 6 with the aid of several engineers from the Caterpillar Tractor Co. and an audience of 200 members and guests. C. G. Rosen, member A.S.M.E., directed the session. He and the other engineers attempted to answer 48 questions submitted by the audience. If the question were improperly answered in the opinion of three faculty judges, anyone in the audience could win a dollar by answering it correctly. Needless to say, several of the boys did win some money. The questions asked pertained to all phases and uses of the Diesel engine. During the intermission, a 50,000-psi Diesel injection pump was used to cut a wood plank in half.

IOWA BRANCH had student papers presented at the Dec. 4 meeting by Logan, Karchefsky, Colony, and Lindholm. At the Dec. 11 session, Prof. C. T. G. Looney gave a lecture on "Impact on Railway Bridges," based on his experiments on the subject.

IOWA STATE BRANCH devoted its Dec. 3 meeting to a long list of all kinds of announcements and to a series of talks by student members. The secretary, Bob Rusk, however, failed to give their names in his report of the meeting.

KENTUCKY BRANCH had a good turnout for the Dec. 6 meeting of 58 members since it was the day when the group picture was taken for the school yearbook. The same number turned out on Dec. 13 to hear a talk on religion presented by Bart M. Peak, Y.M.C.A. secretary.

M.I.T. BRANCH met on Dec. 6 and heard P. J. Reeves, Timken Roller Bearing Co., talk on the "Development of Design and Fabrication of Tapered Bearings." The paper was illustrated with slides and a reel of high-speed movies.

Michigan Professors Roasted

The annual MICHIGAN BRANCH A.S.M.E. Roast was held on Dec. 10 at the Michigan League. There were present 25 members and 58 visitors. Prof. Ben Dushnik was the winner of the contest to find the "man who can take it" and received the "Spoofuncup" award from last year's winner, Prof. Henry L. Kohler. Other contestants were W. F. Bone, J. H. Cissel, L. N. Holland, and A. H. White, all faculty members in the college of engineering. Prof. Walter C. Sadler acted as "roastmaster" for the occasion.

MISSISSIPPI STATE BRANCH had 134 members and guests present at the Dec. 18 meeting to see a motion picture entitled "Wings of the Army," which showed the development of American military aviation. In order to accommodate the large audience, two showings of the film were necessary.

MISSOURI MINES BRANCH sent in a picture which appears elsewhere in this section.

NEVADA BRANCH made plans at its Nov. 21 meeting for a series of motion pictures to be presented during the spring term.

N.Y.U. BRANCH (mechanical) took a trip during December to the Sheffield milk-pasteurizing plant in New York City. After a talk by Mrs. Emmets, company hostess, on the milk industry which stretches from the cow to the consumer, the 30 members were taken on a tour of the plant. In conclusion, milk and sandwiches were served by the company to the boys. Plans are now under way to visit a brewery.

N.Y.U. BRANCH (aeronautical) spent the time of the meeting of Dec. 11 on a group discussion of the advantages and disadvantages of the tricycle and conventional landing gears. Eugene Mehnert led the discussion.

N.Y.U. BRANCH (evening) met on Dec. 4 at Washington Square. Raymond Lepesquer, an alumnus, delivered a talk on sociology and its effect on the engineer of today.

Newark Aviation Talk Draws 225

With members of the A.I.E.E. chapter as guests, the NEWARK BRANCH held a meeting on Nov. 13 at which Bernard Dunlop, ensign in the U. S. Navy, described to 225 students some of the activities of the Naval Air Corps and the opportunities open for engineers in

naval aviation. To illustrate his talk, the speaker showed two motion pictures on the various activities of the American Navy.

NORTH DAKOTA AGRICULTURAL BRANCH members saw a film, "Wheels Across India," at the Nov. 28 session.

NORTHWESTERN BRANCH reports that a materials-testing laboratory for the purpose of studying the behavior of metals, concrete, wood, plastics, and other materials under strain and pressure is being established at the University. The equipment for the new laboratory, most of which has already been ordered, represents a part of the $900,000 worth of new machinery and equipment that will be installed in the classrooms and laboratories of the new school building when it is completed sometime next fall.

Large Membership at Notre Dame

Frank R. Cross, secretary of NOTRE DAME BRANCH, reports that as a result of an intensive membership drive, 100 per cent of the seniors and 97 per cent of the juniors eligible for membership have joined the A.S.M.E. At the Dec. 3 technical session, 65 were present to hear Wayne J. Morrell, General Electric Co., talk on his work which consists of finding ways to eliminate vibration in small engines. A mechanical demonstration and slides were used to illustrate the various methods described in the paper.

OHIO STATE BRANCH dispensed with its regular program at the Dec. 6 meeting so that the 112 members could discuss the weighty problem of the mechanical engineers' lounge. The net result of all the discussion was that it was voted to subscribe to *Life*, *Esquire*, and *Colliers* in order to provide reading matter for the lounge. One member was brash enough to suggest that fees should be charged for using the lounge. Needless to say, his suggestion was not adopted.

PENNSYLVANIA STATE BRANCH had a little difficulty in starting its meeting of Dec. 12 since its regular meeting room was occupied by another group. After the meeting was brought to order in the lobby, the Branch was able to get into its room after the usurping group was officially evicted. This made it possible for P. J. Reeves, Timken Roller Bearing Co., to give his talk on "The Design and Fabrication of Tapered Roller Bearings."

High-Pressure Piping at R.P.I.

For the Dec. 18 meeting, 60 members and 7 guests of R.P.I. BRANCH were on hand to welcome Vincent Malcolm, director of research, Chapman Valve Manufacturing Co., the guest speaker of the evening. He gave a paper illustrated with slides of high-pressure piping as used in modern industry. After a lively discussion, Louis Leibl described his experiences at the A.S.M.E. Annual Meeting in New York.

RICE BRANCH postponed its regular meeting on Dec. 19 so that the members could attend another one sponsored by the school's alumni group. Robert Cummins, consulting engineer of Houston, Texas, was the guest speaker. He discussed the $30,000,000 project under way to prevent floods in and about Houston.

STEVENS BRANCH was host to members of the Stevens Engineering Society on Dec. 18 at a "mass" meeting which featured a talk on "Hundred-Horsepower Hands," by Maxwell C. Maxwell, Yale & Towne Mfg. Co. The talk was illustrated and supplemented with motion pictures.

TUFTS BRANCH had Mr. Maxwell as a speaker the next day, Dec. 19. In his talk, the speaker described the various types of materials-handling equipment available today.

VERMONT BRANCH devoted its Dec. 12 session to a series of talks by student members. The last speaker, a freshman, deviated from the technical theme by presenting feats of magic. About this time it was decided to partake of the ice cream and cookies.

Texas Boy Tells of Big City

W. R. Benson, who attended the A.S.M.E. Annual Meeting in New York, told 87 of his fellow members in TEXAS A.&M. BRANCH of his experiences and hoped that some day each mechanical-engineering student would be able to attend one of these meetings. Two sound movies, "Yellowstone National Park," and "The New York World's Fair," were then shown.

GEORGE WASHINGTON BRANCH had an interesting meeting on Nov. 6 when a representative of the Glenn L. Martin Aircraft Corp. showed motion pictures and slides on the testing of the "Clipper" airplanes.

WASHINGTON BRANCH secretary Eugene Wallace reports that on Nov. 22 a special trip was made to the Alton Boxboard Company in conjunction with the St. Louis Section of the A.S.M.E. He says that the trip was interesting from a gastronomical as well as a technical viewpoint due to an excellent meal which

A.S.M.E. Student Branch Members Are Urged to Submit Papers for Charles T. Main Award of $150

IN THE Charles T. Main Award to A.S.M.E. Student Branch members, there is an unusual opportunity for an undergraduate not only to gain one hundred and fifty dollars but to distinguish himself as the winner of a most sought-after honor.

A cash award of $150, established in 1919, from a fund created by Charles T. Main, past-president of the Society, is awarded annually with an engraved certificate to a student member of the Society for the best paper submitted to the Board of Honors and Awards on a subject selected by the Board and approved by Council. The subject for 1941 is "The Need and Possibilities of Participation by Engineers in Public Affairs," and the paper, containing not less than 2000 words, must be submitted on or before June 30, 1941.

The names of the recipients of the Charles T. Main Award from the first year of its presentation, 1925, to the present, together with the schools they represented and the titles of their papers, are given on this page. Brief biographical sketches of the careers of these men (to 1938) appear in MECHANICAL ENGINEERING for November, 1938, pages 857–859.

The Award is presented annually at the Annual Meeting of the A.S.M.E. held in December, and the winner of this particular prize has his expenses paid to the Annual Meeting.

Recipients of Charles T. Main Award, 1925–1940

1925 "The Influence of the Locomotive on the Unity of the United States," by Clement R. Brown, Catholic University of America.

1926 "The Effect of the Cotton Gin Upon the History of the United States During Its First Seventy Years," by Willard C. Saylor, Johns Hopkins University.

1928 "Scientific Management and Its Effect Upon Manufacturing," by Robert M. Meyer, Newark College of Engineering.

1930 "The Value of the Safety Movement in the Industries," by Jules Podnossoff, Brooklyn Polytechnic Institute.

1931 "Interchangeability — Its Development and Significance in Industry," by Robert Elmer Klise, University of Michigan.

1932 "Apprenticeship and Vocational Training," by Marshall Anderson, University of Michigan.

1933 "Progress in the Prevention of Smoke and Atmospheric Pollution," by George D. Wilkinson, Jr., Newark College of Engineering.

1934 "Air Conditioning—Its Practicability and Relation to Public Welfare," by Philip P. Self, Colorado State College.

1935 "Coördinated Transportation—An Economic Comparison of Railroad, Bus, Truck, Water, and Air Transportation for Long and Short Haul," by G. Lowell Williams, Lafayette College.

1937 "The Influence of the Introduction of Labor-Saving Machinery Upon Employment in the United States," by Allan P. Stern, Case School of Applied Science.

1938 "Economic Limitations in Engineering Design—With Concrete Examples," by Edward W. Connolly, University of Detroit.

1939 "The Economics of Investment in New Manufacturing Equipment—With Concrete Cases," by James R. Bright, Lehigh University.

1940 "What Has Been the Effect of Technological Advance on Employment," by Frank DePould, Case School of Applied Science.

was served by the company to the visitors.

WISCONSIN BRANCH at the Dec. 12 meeting heard talks presented on ordnance by Lieutenant Neighbors and Major Hahn, VI Corps, U. S. Army. They showed the great need of engineers in ordnance work. In the discussion that followed the talks, many questions were asked and answered.

225 at Worcester Session

A rather belated report from Secretary Chandler Walker tells of a meeting held by WORCESTER BRANCH on Oct. 22 and attended by 225 members and guests. After Gunnar Holstrom, engineer with the Norton Company, had outlined the advantages of membership in the A.S.M.E., Prof. Charles Allen gave his ever-popular "gas talk." Even though the talk was humorous, the students learned a great deal. The meeting was closed with the serving of doughnuts and cider.

Institute of the Aeronautical Sciences Announces 1941 Officers

THE Institute of the Aeronautical Sciences has announced the election as president for 1941 of Frank W. Caldwell, director of research of the United Aircraft Corporation, East Hartford, Conn. Other officers elected by the Council of the Institute are: Vice-presidents, W. A. M. Burden of National Aviation Corporation, New York; Charles H. Colvin, chief of the instrument division of the U. S. Weather Bureau, Washington, D. C.; Hall L. Hibbard, vice-president and chief engineer of Lockheed Aircraft Corporation, Burbank, Calif.; Philip G. Johnson, member A.S.M.E., president and general manager of Boeing Aircraft Company, Seattle, Wash.; and Lester D. Gardner, associate A.S.M.E., elected executive vice-president. Grover Loening, consulting aeronautical engineer, was elected treasurer and C. E. Sinclair, secretary.

Mr. Caldwell and the other officers elected for 1941 will be inducted at the Institute's Honors Night dinner in New York on January 28 by Major James H. Doolittle, retiring president.

Lawrence Sperry Award to W. Bailey Oswald

THE Lawrence Sperry Award for 1940 has been awarded by the Institute of the Aeronautical Sciences to Dr. W. Bailey Oswald of the Douglas Aircraft Company. Presentation is to be made at the Honors Night dinner of the Institute, New York, N. Y., Jan. 28, 1941. The Sperry Award, with an honorarium of $250, is conferred annually for a notable contribution made by a young man to the advancement of aeronautics. It was endowed by the brothers and sister of the late Lawrence Sperry, pioneer aviator and inventor, who was drowned at the age of 31 as the result of a forced landing in the English Channel in 1923.

Dr. Oswald was chosen to receive the award for 1940 by a committee whose members are Major James H. Doolittle, Lester D. Gardner, Charles L. Lawrance, Grover Loening, Glenn L. Martin, and Elmer A. Sperry, Jr. Their citation accompanying the award is "for analytical studies in aerodynamics which have greatly facilitated the accurate design and economical operation of airplanes."

Two A.S.M.E. Members Receive Hydraulic Institute Prizes

AT ITS annual meeting on Dec. 2, 1940, the Hydraulic Institute, a national association of pump manufacturers, presented three awards to the winners of its first annual engineering essay contest. The first prize was awarded to I. J. Karassik, Jun. A.S.M.E., for his paper "Thermodynamics of Boiler Feeding." Prizes were also awarded to Hans Gartmann, Mem. A.S.M.E., and Hollis T. Waldo for their papers "The Operation of Centrifugal Boiler Feed Pumps" and "Submergence for Centrifugal Condensate Pumps."

Bibliography on Airplane Hangars

CURRENT interest in all matters connected with aviation has prompted the Engineering Societies Library to prepare a list of references on the Design and Construction of Airplane Hangars. The list includes one hundred articles selected from those published during the years 1928–1940 in the leading domestic and foreign periodicals, and contains material on both steel and reinforced-concrete structures.

Copies may be obtained by sending two dollars to the Engineering Societies Library, 29 West 39th Street, New York, N. Y.

Tobey Appointed to Ohio Registration Board

JULIAN E. TOBEY, member A.S.M.E. has been appointed by Governor Bricker, of Ohio, a member of the Ohio State Board of Registration for Engineers and Surveyors.

Nomination Due by Feb. 15 for Spirit of St. Louis Junior Award

ALL agencies of the A.S.M.E. including Local Sections, Professional Divisions, and others who have had charge of arranging programs for the last three years and particularly members interested in the Aeronautic Division should take heed of the fact that the Board of Honors and Awards is about to make a decision as to which Junior member is entitled to receive the Spirit of St. Louis Junior Award for 1941.

The award will be made to a member of the Society who, while a Junior under thirty years of age, presented a paper at some meeting of the Society on a subject within the category of aeronautics. This paper should have been presented during the years 1938, 1939, and 1940.

Any A.S.M E member wishing to make a recommendation should forward it at once and not later than February 15, 1941, to Joseph W. Roe, chairman of the Board of Honors and Awards, at the A.S.M.E. headquarters, 29 West 39th St., New York, N. Y.

Hugh L. Dryden Receives Sylvanus Albert Reed Award

HUGH L. DRYDEN of the National Bureau of Standards, member A.S.M.E., has been chosen by the Fellows of the Institute of the Aeronautical Sciences as the 1940 recipient of the Sylvanus Albert Reed Award which is conferred annually for notable contributions to the sciences relating to aeronautics. Presentation of the award will take place at the Institute's Honors Night dinner in New York on January 28. Dr. Dryden has been named for this honor "for his contributions to the mechanics of boundary-layer flow and to the interpretation of wind-tunnel experiments." He is chief of the Mechanics and Sound Division of the National Bureau of Standards and has been on the staff of the Bureau since 1918. He is secretary of the A.S.M.E. Applied Mechanics Division.

A.S.M.E. Local Sections

Coming Meetings

Baltimore. February 24. Engineers Club of Baltimore at 8:15 p.m. Subject: "Industrial Mobilization," by Lieut. Col. L. A. Codd, executive vice-president of the Army Ordnance Association, Washington, D. C.

Columbus. February 21, 1941. Fort Hayes Hotel at 8:00 p.m. Subject: "What's Ahead for the Engineer," by Past-President Warren H. McBryde, consulting engineering of San Francisco, Calif.

Detroit. February 4. L'Aiglon, Fisher Building at 6:30 p.m. Subject: "Rubber—A Universal Material in New and Varied Uses," by Sidney M. Cadwell, development manager, United States Rubber Company.

New Haven. February 18. Mason Laboratory, Yale University, at 8:00 p.m. Joint meeting with the Yale Student Branch. The subject of the meeting will be devoted to aeronautics and Grover Loening, consulting aeronautical engineer, will be the speaker.

Philadelphia. February 25. Engineers Club, 1317 Spruce St., Philadelphia, Pa., at 7:30 p.m. Subject: "Modern Power," by Nevin E. Funk, vice-president in charge of engineering, Philadelphia Electric Company. Preceding Mr. Funk's talk E. G. Bailey, vice-president, Babcock & Wilcox Company, will present colored motion pictures of actual combustion conditions in stoker and pulverized-fuel-fired furnaces.

(*A.S.M.E. News continued on page 170*)

*An open message to Johns-Manville Employees**

by LEWIS H. BROWN, *President, Johns-Manville Corp.*

AS THIS NEW YEAR BEGINS, I am glad to have this opportunity to discuss with you the big job facing all of us during 1941.

Because of the demands placed on every business and every citizen by our nation's need for an adequate defense, our work is clearly cut out for us. We must contribute to the utmost of our ability to the defense building program.

Already, one-third of all J-M production is demanded for defense requirements. And this demand is growing daily. Some of it has been due to the increased need for J-M products for direct government projects. Some of it is the result of sales to expanding industries which use our products and are themselves working at top speed to fill government orders.

* * *

With every increased demand Johns-Manville has stepped up production to meet it. Many departments of our seventeen mines and plants have been affected by the defense needs and are now operating seven days a week, 24 hours a day. The working day is divided into three shifts of eight hours. At many locations, four shifts of employees work 40 hours each week to assure full production of the machines 7 days a week. Thus, work on Saturdays and Sundays is distributed fairly among everybody affected.

As the defense program develops we will necessarily have to step up our production more and more. This means we will have to find all the "bottlenecks" and increase the productivity of every machine.

Of course, most of us would prefer that industry's policy could be "business as usual." But these are not normal times. Business cannot be conducted "as usual" in an emergency. Defense comes first.

* * *

As a company, J-M is not going to let anything or anybody stand in the way of expediting the government's efforts to complete the defense program. This means co-operation by all of us, by management and by employees.

Naturally we shall all be called upon to make sacrifices. Taxes will be heavier. Raw material and manufacturing costs will probably rise. We shall all have to bear the burden.

Under these circumstances we shall have to redouble our efforts to reduce waste and increase efficiency so that we not only will be able to deliver quality goods in record time, but keep prices in check. By doing this we shall be helping to keep the costs of the defense program down. As taxpayers we shall indirectly benefit through this economy, for all of us must pay our share of the enormous defense bill.

* * *

There is no doubt in my mind that J-M jobholders can be relied upon to do their part. You have already shown the spirit of real co-operation and patriotism which is so necessary. For your co-operation I want to thank you.

I know that I can count upon your continued support and loyalty in our common effort to help keep this land of ours safe and free.

May I take this opportunity to wish for all of you health and happiness during this new year?

Lewis H. Brown

**Although not directly engaged in the manufacture of munitions or armaments, Johns-Manville manufactures many products essential to the operation of industries so engaged. This message, stating Johns-Manville's policy in support of the nation's defense program, originally appeared in the January, 1941, issue of the* News Pictorial, *J-M employee magazine.*

Men and Positions Available

Send inquiries to New York Office of Engineering Societies Personnel Service, Inc.

29 W. 39th St. New York, N. Y. — 211 West Wacker Drive Chicago, Ill. — 57 Post Street San Francisco, Calif. — Hotel Statler Detroit, Mich.

MEN AVAILABLE[1]

MACHINE-TOOL ENGINEER with proved ability for designing and manufacturing machine tools for heavy industries and ordnance. Desires connection, charge of either design or manager of manufacturing of machine tools. Me-587.

DESIGN AND DEVELOPMENT ENGINEER, 29, married. Broad experience including shop practice, patents, supervision of draftsmen and machinists. Specialty, development of precision instruments and machines. Available, two weeks. Prefer Southern California. Me-588.

MECHANICAL ENGINEERING GRADUATE, 24, B.S. in M.E. 1939. Assistant in college physics laboratory 4 months; rate-setting 5 months; 7 months production control, planning, cost analysis. Now employed, desires change. Me-589.

DESIGNING ENGINEER, 43, Master's degree in mechanical engineering. Twenty years' experience in mechanical and electrical apparatus, inventive, aggressive, practical, supervision over engineering and drafting department, permanent position. Now employed. Registered. Me-590.

MECHANICAL AND ELECTRICAL ENGINEER with 20 years' experience in directing many engineers and men working on design, construction, and operation of large industrial plants. Available now. Me-591.

EXECUTIVE ENGINEER with over 20 years' experience in design for economical production as well as development work covering diversified field of machinery. Has knowledge of mass production, cost, and sales. A good executive. Me-592.

MECHANICAL ENGINEER, 22, single, B.S. 1940. Honor graduate, believes hard work can somewhat offset lack of experience. Interested in design, does not shirk responsibilities. Will go anywhere in U. S. Me-593.

MECHANICAL ENGINEER, 26, married, Stevens 1935. Four years' experience in general project work, economic studies, design and development of factory methods. Now employed, desires change in position. Me-594.

GRADUATE MECHANICAL ENGINEER, 44, specialist internal-combustion engines, diversified manufacturing and field training, consulting and lecture experience. Desires connection in commercial or engineering capacity with manufacturer, agency, or consulting engineers. Me-595.

AERONAUTICAL ENGINEER, 11 years of broad experience as chief engineer and project engineer, 9 years in charge of experimental and research work, designing special aircraft equipment, technical adviser, service-acceptance trials. Me-596.

LUBRICATION ENGINEER, B.S. in M.E., M.S., 28, married. Now employed as industrial lubricants salesman, by major oil company. Familiar all phases blending, marketing, and distributing petroleum products. Seek sales-engineering position, same or affiliated industry. Will travel. Me-597.

MANUFACTURING PLANT MANAGER OR CHIEF ENGINEER, 46, single. Technical graduate with broad general mechanical- and electrical-engineering experience. Successful plant executive (diversified woodworking) organizer, systematizer, coordinator. Now employed. Me-598.

MECHANICAL ENGINEER, 39 years old, married. Experience: 3 years shipbuilding; 11 years materials-handling equipment; 7 years with food and chemical plant as assistant to plant engineer on new equipment and new expansion. Me-599.

GRADUATE MECHANICAL ENGINEER, Cornell University, M.E. 1935. Anglo-Saxon, American citizen. Time study $1^1/_2$ years. Design work, $2^1/_2$ years on small production mechanisms. Desires designing position. Me-600.

[1] All men listed hold some form of A.S.M.E. membership.

Atlanta Convention Bureau

WREN'S NEST, HOME OF JOEL CHANDLER HARRIS, IN ATLANTA, GA.

(See pages 158–159 of this issue.)

POSITIONS AVAILABLE

CHIEF INSPECTOR, preferably graduate mechanical or chemical engineer, to supervise inspection in process industry. Must be capable of instructing other inspectors and supervising their work in plant in which there must be no mistakes. Salary open. South. Y-7146.

CHIEF ENGINEER, 33–40, graduate mechanical, who has had machine-tool experience. Salary open. Middle West. Y-7148.

TIME-STUDY ENGINEERS, not over 35, graduate mechanical, with machine-shop practice. Ohio. Y-7161-D.

DRAFTSMAN with good experience and capable of designing such work as press tools, jigs, and milling fixtures. Should also be capable of checking work of other draftsmen. New England. Y-7165.

SALES ENGINEER, not over 30, married, graduate mechanical, with sales experience, preferably steam work. Will call directly on trade within territory, including industrial concerns, utilities, consulting engineers, contractors, etc. Will also work with jobber salesmen. Territory, Michigan and western Ohio with headquarters at Detroit. Y-7166.

MACHINE DESIGNER to lay out cams, gears, and punch presses. Able to make flywheel calculations. Salary open. New Jersey. Y-7182.

TOOL DESIGNER, precision-instrument experience. Salary open. New York, N. Y. Y-7185.

PERSONNEL MANAGER for 1000-man plant. Should have some experience and be willing to start at modest salary. New England. Y-7192.

DESIGNERS with good experience in water supply and purification; pumping; piping of all kinds, particularly acid and other process piping if possible; steam lines and power-plant work; sewage disposal. Men should be able to design and lay out work and supervise draftsmen in making working drawings. Salary up to $90 a week depending upon experience. Delaware. Y-7194-C.

PLANT SUPERINTENDENT for company manufacturing metallurgical products. Applicant must have experience in installation and maintenance of equipment to operate small, rapidly expanding, new plant. East. Y-7211.

PLANT MANAGER OR SUPERINTENDENT to assume complete responsibility for production in well-established company manufacturing gold rings and mountings. Must be thoroughly experienced in modern methods of mass production; know ring design, diemaking, production control, methods study, and cost finding. Liberal compensation. East. Y-7219.

DESIGNING ENGINEER with 5 to 10 years' experience in buildings and industrial furnaces or heavy machinery. Salary open. New Jersey. Y-7234.

PROCESS ENGINEERS for processing work on light and heavy machine tools, working to close tolerances. Should have good mechanical background; prefer applicants who served an apprenticeship and later did processing, time-study work, and estimating. Men should be capable of processing work from blueprints, indicating machine tool on which the operations should be performed, type of fixtures required, and estimate of time of each operation. Pennsylvania. Y-7236.

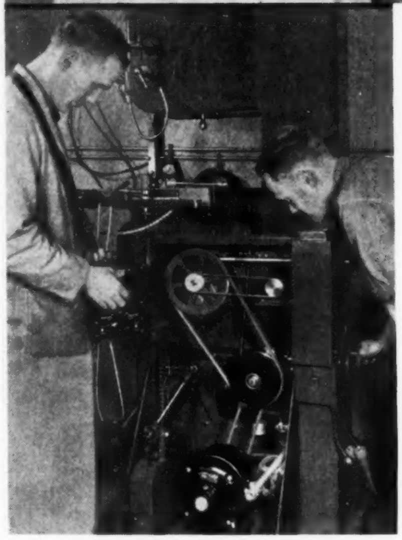
DESIGN ENGINEER, mechanical and electrical, preferably not over 45, experienced in design of small, complicated, mechanical-electrical machines. Familiarity with recording practice beneficial. New England. Y-7237.

GRADUATE MECHANICAL ENGINEERS, 2, preferably under 30, with some working experience. One man is wanted for checking drawings, especially for checking accuracy of gears, shafts, and bearing sizes. Salary, about $250 a month. Other applicant is wanted for designing speed reducers and other large-size mechanical apparatus. Salary, about $200 a month. Pennsylvania. Y-7248.

RECENT GRADUATE ENGINEERS, not more than two years out of school, for product-engineering division of large manufacturing com-

(*A.S.M.E. News continued on page 172*)

Photo Courtesy Continental Machines, Inc.



By setting the SPEEDMASTER at any of its infinite number of positions, the belt positions in relation to the sheaves can be determined immediately with the STROBOTAC. Any small irregularities in the center distances of the sheaves will show up immediately in vibration and shifting of the center pulley. The effect of various torques at different angular velocities of the pulley can be studied easily, making it possible to isolate and correct any vibration or excessive slippage.

DESIGNING BAND SAWS

CONTINENTAL MACHINES and its associated DoAll Company have been using the General Radio STROBOTAC for some time in the design of both Internal-External Contour Sawing and Band Filing machines and DoAll band saws, extensively used in production.

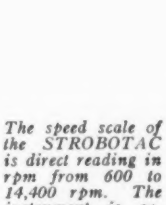
In their Laboratories the operation of a DoAll band saw, while cutting a slab of transparent plastic, is being observed with the STROBOTAC to see the exact action of the teeth and to isolate, analyze and correct vibration.

All DoAll machines are equipped with a Speedmaster Variable Speed pulley by means of which any saw speed from 50 to 1600 feet of travel per minute can be obtained. The STROBOTAC is being used to study the mechanics of the Speedmaster, to check its operation, to watch for excessive belt slippage, etc.

Without the STROBOTAC the observation of the precise functioning of many parts of these machines would be very difficult if not impossible. The STROBOTAC is very simple to use, is light-weight, portable, self-contained and accurate, and can assist you if you would like to see exactly how your equipment operates at any speed from 100 rpm to 100,000 rpm. It is, as well, an accurate electrical tachometer, reading directly in rpm from 600 to 14,400 with no mechanical or electrical connection to the machine being checked . . . and it is moderately priced at only $95.00.

The STROBOTAC has helped thousands of design, research, production, maintenance and sales engineers. It can help you. Let us show you how.

The speed scale of the STROBOTAC is direct reading in rpm from 600 to 14,400 rpm. The instrument is accurate to 1% and is proving invaluable in measuring the speed of any reciprocating or rotating machine or part, in addition to showing in s-l-o-w motion the exact operation of the machine.



• ***WRITE FOR BULLETIN 669***

GENERAL RADIO COMPANY

Cambridge, Massachusetts

BRANCHES: NEW YORK AND LOS ANGELES

MANUFACTURERS of PRECISION ELECTRICAL LABORATORY APPARATUS

pany. Men will start work in drafting room and their possible advancement will be through design section and into staff engineering section. Product engineering division prepares drawings and specifications for new models and assists production department in placing company's product in production. Ohio. Y-7251-D.

FACTORY MANAGER, well versed in machine-shop work in milling, drilling, grinding, punch press, medium-to-small intricate assembly work. Also must know thoroughly methods of planned production and coordination of costs, inventory control; must possess good personality and have ability to lead. Non-union shop of about 300 male employees; working conditions excellent. Salary, $5000 a year to start. East. Y-7255.

GRADUATE ENGINEER experienced in design and layout of power plants for development of industrial power plant. Should be capable of handling complete design of power plant and have 10 years' experience along this line. Will be required to assist in preparation of studies on which major items of equipment would be decided and to develop and complete design of entire power plant when decision is reached. Salary, approximately $80 a week. New England. Y-7260.

DESIGNING ENGINEER, young, for engineering research staff. Must be qualified to design small and medium-sized machinery for producing bread. Knowledge of bread production, however, is not essential. Should have ability machine designing, engineering drawing; knowledge applied mechanics, mechanical engineering. Middle West. Y-7270-C.

DESIGNER on knitted fabrics who is capable of laying out blends as well as directing knitting and finishing of woolen coatings for men's and women's wear. New York State. Y-7271.

MECHANICAL ENGINEER to supervise production and development of small precise mechanisms. Must be experienced in power-press, screw-machine, gear-cutting machines, and power-press assembly work; should have understanding of electric-motor operation, time-delay relays, timers, etc., and close precision work on small gears. Small electro-mechanical instrument manufacturing experience beneficial. Salary open. Connecticut. Y-7285.

Candidates for Membership and Transfer in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after February 25, 1941, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member who has either comments or objections should write to the secretary of The American Society of Mechanical Engineers immediately.

KEY TO ABBREVIATIONS

Re = Re-election; Rt = Reinstatement; Rt & T = Reinstatement and transfer to Member

NEW APPLICATIONS

For Member, Associate, or Junior

ARRIGO, PAUL A., Ferguson, Mo.
BABIN, ALEXANDER, New York, N. Y.
BASKERVILLE, RALPH J., Yeadon, Pa.
BASSETT, WM. V., West Newton, Mass.
BOETTCHER, RICHARD A., Inglewood, Calif. (Re)
BRANDON, RAYMOND J., Detroit, Mich. (Rt & T)
BRUMBAUGH, CHESTER C., Painesville, O. (Rt)
CLAYTON, MARK M., Portland, Ore.
CLIFFE, EDWIN L., Tacoma, Wash.
CUTHBERT, STUART V., New York, N. Y.
DEMARCO, ALLEN V., Springfield, Mass.
ELLIOT, WALTER G., Columbia, Mo.
ERNEST, E. W., Schenectady, N. Y.
GONZALEZ, M. A., Central Juand Caguas, P. R.
GORDON, HAYDON S., Davis, Calif.
HALL, JOHN M., Washington, D. C.
HAMILTON, S. L., Stuart, Fla.
HARRINGTON, J. V., New London, Conn.
HILL, HAROLD O., Bethlehem, Pa.
HUDSON, W. G., Chicago, Ill. (Rt)
ISHIKAWA, YUZO, New York, N. Y.
JOHNSON, PAUL A., Seattle, Wash.
JOHNSON, ROY F., Michigan City, Ind.
KINNEY, JAS. J., Washington, D. C.
KORTEN, ELMER C., Weathersfield, Conn. (Rt & T)
LAMB, GEO. G., Whiting, Ind.
LANGER, GEO. B., Anderson, Ind.
LANGHAMMER, WM. P., Winchester, Mass.
LEBA, STEVEN J., Minneapolis, Minn.
LINDSTROM, ALVIN L., Atlanta, Ga.
LLOYD, FRANK H., Rochester, N. Y.
LOODEN, JAS. K., Pittsburgh, Pa.
MACDONELL, V. E., Metuchen, N. J.
MANVELL, THEO. J., North Bergen, N. J.
MEIER, WM. G., New York, N. Y.
MILLER, K. O., Philadelphia, Pa.
MORRO, JOHN J., New York, N. Y.
MUZICKA, ANTHONY, Troy, N. Y.
NETTEL, FREDK., New York, N. Y.
NEUMANN, MICHAEL, New York, N. Y.
PAULSON, ELMER I., Saugus, Mass.
PETERSON, KNUTE L., Chicago, Ill.
RALL, EDWIN B., Detroit, Mich.
RILEY, C., Guatemala City, C. A.
ROBERTS, K. D., Plymouth, Mass.
ROCKWELL, THEO. F., Pittsburgh, Pa. (Rt & T)
ROOT, ALBERT B., Waban, Mass.
SANDOR, GEORGE, New London, Conn.
SCRIBNER, CLAUDE L., Elgin, Ill.
SMITH, EUGENE W., Dallas, Texas
SWANSON, NILS E., New York, N. Y.
TEDROW, GEO. E., Seattle, Wash.
TRITTLE, EDW. M., Lynn, Mass.
WARD, WINSLOW A., Rochester, N. Y.
WARMING, TROELS, Milwaukee, Wis.
WERY, ALBERT G., Teaneck, N. J.
WHITE, ELLIS E., New York, N. Y.
WHITLEY, JAMES B., Houston, Texas
WYMAN, L. A., Cincinnati, Ohio (Rt & T)
YOUNG, EDW. W., Rahway, N. J.

CHANGE OF GRADING

Transfers to Fellow

BAUSCH, CARL L., Rochester, N. Y.
KEELER, HUGH E., Ann Arbor, Mich.

Transfers to Member

ALDRICH, RICHARD C., New York, N. Y.
ALT, LOUIS M., Lafayette, Ind.
BRADLEY, EARL H., Seekonk, Mass.
BROWN, T. C., Raleigh, N. C.
BURR, A. H., Houston, Texas
COOGAN, CHAS. H., JR., Philadelphia, Pa.
DECKER, HAROLD A., Rochester, N. Y.
ELLENBERGER, WM. J., Washington, D. C.
FLETCHER, J. LOREN, Evansville, Ind.
GREEN, GEO. C., Somerville, N. J.
KEENER, H. JAS., Long Island City, N. Y.
KRAUSE, ROBT. M., Homewood, Ill.
MCMAHAN, R. C., Lapel, Ind.
MURRAY, W. MACG., Cambridge, Mass.
OLSEN, OLAF LACOUR, Houston, Texas
PERKINS, SUMNER E., Burbank, Calif.
PESQUEIRA, J. J., New York, N. Y.
PRINGLE, EDW. S., Norfolk, Va.
RUST, G. M., Birmingham, Ala.
SALMA, EMANUEL A., New York, N. Y.
TITUS, E. S., Fountain City, Tenn.
TRAVER, ALFRED E., Brooklyn, N. Y.
VIERCK, ROBT. K., Washington, D. C.

Transfers from Student-Member to Junior—9

A.S.M.E. Transactions for January, 1941

THE January, 1941, issue of the Transactions of the A.S.M.E. contains:

The Trend of Air Transportation, by E. T. Allen
An Improved Technique for Centrifugal-Pump-Efficiency Measurements, by R. W. Angus
A Theory of Cavitation Flow in Centrifugal-Pump Impellers, by C. A. Gongwer
Turbulence and Energy Dissipation, by A. A. Kalinske
Progress in Design and Performance of Modern Large Steam Turbines for Generator Drive, by G. B. Warren

Necrology

THE deaths of the following members have recently been reported to the Society:

BORDEN, WILLIAM H., September 8, 1940
CRISSEY, CLARENCE P., October 9, 1940
FOSTER, WILLIAM I., July 7, 1940
HONISS, WILLIAM H., August 23, 1940
HUMPHREY, GEORGE S., December 3, 1940
NELSON, GEORGE H., June 11, 1939
OGDEN, EARL F., October 20, 1940
RAB, JOHN, October 18, 1940
SEAMAN, HENRY B., October 24, 1940
TABER, GEORGE H., December 10, 1940
WIGGIN, CHARLES, JR., October 31, 1940
WOODWARD, ELMER E., December 31, 1940